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Rehabilitation interventions after hand burn injury in adults: A systematic review

Zoë Edger-Lacoursière[a,b,c], *Erika Deziel*[c], *Bernadette Nedelec*[a,b,*]

[a] School of Physical and Occupational Therapy, McGill University, Montreal, QC H3A 0G4, Canada
[b] Hôpital de Réadaptation Villa Medica, Montreal, QC H2X 1C9, Canada
[c] Centre Professionnel d'Ergothérapie, Montreal, QC H1N 1E5, Canada

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ABSTRACT

The aim of this review was to summarise the current evidence regarding the effectiveness of rehabilitation interventions in improving hand function, range of motion (ROM), hand strength, scar outcome, return to work, level of impairment/disability, level of burn knowledge and decreasing edema following hand burns in adult burn survivors. This review provides evidence-based support for the use of rehabilitation interventions for burn rehabilitation professionals. The following data sources were searched: MEDLINE, EMBASE and CINAHL from their inception up to February 2021, reference lists from all the included full-text articles were screened for additional relevant publications and monthly Google Scholar searches until December 23rd 2021 to make sure all new pertinent published articles after February 2021 would be included. Thirty-five studies were included in this review including 14 RCTs. Most of the included studies were Level 4 (46%; 16/35) and Level 2 (40%; 14/35) evidence. Only four studies were classified as Level 3 (14%; 5/35) evidence and none were considered Level 1. Most studies received a score of 5–9 (54%; 19/35) (Moderate quality). Fourteen studies received a score of $\geq$ 10 (40%; 14/35) (High quality) and only 2 studies received a score of $<$ 5 (6%; 2/35) (Low quality). Articles were categorized according to the primary outcome targeted by the intervention. Clinical recommendations on higher-level evidence interventions are presented. This review supports the clinical practice of the following interventions: 1) The use of adhesive compression wraps for patients who have increased edema to increase hand function and ROM; 2) The use of compression (adhesive compressive wrap, compression bandage or intermittent compression pump) to decrease hand edema following burn injury; 3) Participating in general rehabilitation to increase hand function and patient perceived level of disability; 4) The use of an orthosis to increase ROM and a dynamic MCP orthosis to increase hand function; 5) If available, incorporate the use of VR based rehabilitation to increase hand function and hand strength; 6) The use of paraffin to increase hand PROM; 7) The use of gels to reduce hand scar thickness; 8) The use of an education component in rehabilitation to increase the level of burn knowledge. The limitations of this study are also discussed. Further

* Correspondence to: McGill University, School of Physical and Occupational Therapy, 3654 Promenade Sir William Osler, Montreal, QC, H3G 1Y5, Canada.
E-mail address: bernadette.nedelec@mcgill.ca (B. Nedelec).

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research with robust methodology is needed to investigate the potential benefits of treatment interventions included in this review.

1. Introduction

1.1. *Rationale*

Burn injuries to the hands and upper extremities account for 50–70% of burn injuries in North America [1] and hand burns are one of the three most frequent sites of burn scar contracture deformity [2–4]. Even though the hands correspond to a small total body surface area (TBSA), they have a more complex and delicate anatomy compared to other body parts and their implication in our interactions with the environment make them indispensable to "normal" function [5]. Therefore, hand burns require specialized treatment and this is why the American Burn Association's "Guidelines for the operation of burn centres" includes them as criteria for referral of a patient to a specialized burn centre [6]. In fact, according to Moore et al. [7], some common complications due to hand burn injuries include edema, scar contractures, joint deformities, sensory impairments, loss of skin stability and restricted functional use of the hand, which all require treatment at a specialized facility.

Although hand burns do not contribute to a higher mortality rate, they can cause severe functional impairments since hand function is indispensable to carry out daily activities and requires, but is not limited to, fine and gross dexterity, manipulating objects and various performance skills [8]. Hand burns have also been associated with delayed return to work, which increases costs for the employer and decreases the chances for the employee to successfully return to work [9,10]. Furthermore, a study by Anzarut et al. demonstrated that hand function has a direct impact on the quality of life of burn survivors and is described as a strong predictive factor for reintegrating into society and the work setting [11]. Therefore, regaining optimal hand function is one of the most important goals in burn survivor rehabilitation.

Hand burns differ from other anatomical sites due to their complex anatomy, functional importance, and frequency of burn injury. According to the 2009 burn rehabilitation and research consensus summit [12], experts believe that despite the recognition that the treatment of hand burns is more complex, research specific to hand burns is not more advanced than the research available for other burn sites in terms of patient outcomes. Furthermore, experts from this summit underlined that "*there is currently no consensus regarding treatment of hand burns across the spectrum of severity*". Esselman et al. [13] reported that there was only a small quantity of hand burn literature relevant to the rehabilitation setting and very few randomized controlled trials (RCTs). This lack of high-level evidence in the literature could explain these consensus gaps in clinical practice.

However, since 2009, research specifically addressing hand burns has been growing and studies on interventions to improve patient outcomes have been more frequent [14–16]. Therefore, there is a need to determine what are the best rehabilitation interventions used for the treatment of burned hands. There is also a need to synthesize the current body of high-level evidence that supports these interventions to better inform rehabilitation specialists.

Nonetheless, no systematic review or other type of structured knowledge synthesis has been published on rehabilitation interventions for hand burns.

1.2. *Objectives*

This review aims to summarise and evaluate what rehabilitation interventions are most effective in improving hand function, range of motion (ROM), hand strength, scar outcome, return to work, level of impairment/disability, level of burn knowledge and decreasing edema following hand burns in adult burn survivors.

2. Methods

The PRISMA statement and checklist [17] and the Cochrane Collaboration for systematic reviews [18] were used to guide this review. A research protocol containing the PICO review question, inclusion/exclusion criteria (Table 1) and a search strategy (Appendix 1) was established prior to conducting this review.

2.1. *Selection criteria for including studies*

2.1.1. *Types of studies*

Randomized (RCT) and non-randomized studies (NRS) were included to ensure a thorough evaluation of the effects of the intervention. Case control (CC), case series (CS), single case design (SCD), multiple case design (MCD) and cohort (CO) studies were also included, because the available RCTs and NRSs did not cover the entire scope of rehabilitation interventions for burned hands. Studies in English or French were included.

2.1.2. *Types of participants*

Studies of adults aged 18 years or older who sustained hand burns were included in this review. If studies included both participants aged under and over 18 years of age, and the data presented was combined for all participants, they were included if the mean age was greater than 18 years. If a case series study included patient(s) younger than 18 years old, the data for participants aged 18 years or older only, was extracted. If studies included both participants aged under and over 18 years of age, they were included if the mean age

Table 1 – Systematic review research question and inclusion/exclusion criteria.

Research question: What rehabilitation interventions are most effective in improving hand function, range of motion (ROM), hand strength, scar outcome, return to work, level of impairment/disability, level of burn knowledge and decreasing edema following hand burns in adult burn survivors?

Inclusion Criteria	Exclusion Criteria
Sample includes burn survivors	No burn survivors included in sample
Adult subjects	Pediatric subjects only
Burns sustained to the hands	Burns that exclude the hands
Rehabilitation interventions	Surgical or non-rehabilitation interventions
Evaluated one or more of the following outcomes:	Did not evaluate one or more of the following outcomes:
– burn specific outcome measure	– burn specific outcome measure
– hand specific outcome measure	– hand specific outcome measure
– general function outcome measure	– general function outcome measure
– ROM	– ROM
– hand/grip strength	– hand/grip strength
– need for reconstructive surgery	– need for reconstructive surgery
– scar characteristics: thickness, pliability, erythema, and melanin	– scar characteristics: thickness, pliability erythema, and melanin
– return to work	– return to work
– edema	– edema
– pain	– pain
– level of burn knowledge	– level of burn knowledge
Provided outcome data and methods for determining outcome were described	No outcome data was provided and/or methods of determining outcome were not described
Published in English or French language	Conference abstracts, review papers or papers with no original data
Type of studies: CC=Case control; CS=Case series; SCD/MPD=single case design or multiple case design RCT=randomized controlled trial; CO=cohort; NRS =Non-randomized studies	The study type did not correspond to one of the following: CC=Case control; CS=Case series; SCD/MPD=single case design or multiple case design RCT=randomized controlled trial; CO=cohort; NRS =Non-randomized studies

was greater than 18 years old. No limits were placed on the extent or cause of the burn injury. In studies where participants had burns on their hands and other anatomical locations, only data relative to hand burns was extracted and analyzed.

2.1.3. *Types of interventions*

All types of rehabilitation interventions were included. The experimental group could have no comparison or compared to other rehabilitation interventions. The intervention could be the only treatment or an additional treatment. When multiple interventions were applied, the treatment was considered to be a program. Surgical interventions or therapies conducted by non-rehabilitation specialists were excluded.

2.1.4. *Outcome measures of interest*

The outcomes of interest were hand function, level of impairment/disability, range of motion (ROM), strength, edema, scar characteristics, level of burn knowledge or return to work. The occurrence of any adverse events from the intervention was also assessed.

2.2. *Search strategy*

A search strategy was developed and validated by an academic librarian to identify publications relevant to this review. The following databases were searched electronically: MEDLINE, EMBASE and CINAHL from their inception up to February 2021. In addition to the electronic search, the reference lists were screened from all the included full-text articles for additional relevant publications and monthly Google Scholar searches were conducted until December 23rd 2021 to ensure all new pertinent published articles after February 2021 would be included. The search strategy used for MEDLINE is included in appendix 1.

2.3. *Selection process*

Citations were imported into a reference manager software program (Endnote X9, Clarivate Analytics, Pennsylvania, USA) to remove duplicates. The remaining citations were then exported to an online screening tool (Rayyan, Qatar Computing Research Institute, Doha, Qatar). Two authors (ZEL & BN) independently reviewed the titles and abstracts generated by the literature search. The full text was obtained to further assess if the articles matched the inclusion criteria. In the event of a disagreement, the two authors discussed to achieve consensus. Before discussing, the authors had a 95.85% agreement. Full consensus was reached after discussion.

2.4. *Data extraction and management*

Two authors (ZEL & ED) extracted data from the included studies using a standardised extraction form (Table 2). Each author extracted data for half of the included articles. The authors then reviewed and validated the extracted data for the other half of the articles. In the event of disagreements, discussions between the two authors occurred to achieve

Table 2 – Summary of study characteristics, sociodemographic data, outcome measures, intervention, results, and level of evidence.

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
Aghajanzade et al. [43]	CS-prosp	n = 30 Mean age 35.9 ± 9.9 y old Mean TBSA=20.86%±-14.90	Occupational therapy (OT) – Combination of interventions	1) Hand function (DASH)	24–36 hrs of OT over the course of 8 weeks. Elevation exercises, reversible massage, compression bandages and passive mobilization were used to reduce swelling. Splinting, passive and active mobilizations, and stretching exercises were used to treat scars and prevent contractures.	– Hand function improved - DASH scores 60.9 before OT, 33.9 after. Average change 27 points ($p < 0.001$). – No adverse effects reported.	N/A	4
Ause-Ellias et al. [44]	CS-prosp	n = 5 (9 hands) Mean age = 43.2 y old Mean TBSA= 19.6% Mean Tx start = 22.2 days post hospital discharge Grafted hands: 6/9	Compression (Intermittent compression pump) – One intervention	1) Edema (Volumetry) 2) AROM of MCP and PIP (Goniometry)	The Jobst Intermittent compression pump applied 55 mm Hg pressure with a single-cell unit for 30 min Tx at 4:1 ratio (60 s compression with a deflated 15 s rest period). Each patient underwent approximately 3 Tx during a 2-week trial period. Patients who had 2 burned hands received compression on both hands simultaneously. Patients were positioned supine with the upper extremity elevated on two pillows.	Comparing pre and post-Tx measures: – average hand-volume ↓ by 9.45 ml – average PIP joint flexion ↑ by 3.37° – average MCP joint flexion ↓ by 0.23° – All three results were not statistically significant. – No adverse effects reported.	N/A	4
Choi et al. [15]	RCT	n = 42 with < 61 degrees MCP flexion within 6 m of injury Mean age = 41.4 ± 12.06 y old Control group: n = 21; Mean TBSA = 24.47% ± 18.25 Tx group: n = 21; Mean TBSA = 27.57 ± 23.64	Dynamic MCP orthosis – One intervention	1) AROM of MCP and PIP (Goniometry) 2) Hand function (MHQ, JHFT) 3) Grip strength (Dynamometer) 4) 4) Other: QoL and ADL (BSHS, FIM Korean version)	– **Control group**: No orthosis – **Tx group**: Dynamic MCP joint flexion orthosis worn 3hrs/day for 1 hr at a time for 8w. Time of initiation not described (but injury within 6 m). Both groups received standard rehabilitation.	– Tx group: significant improvement in active flexion of D2/3/4/5 MCP joints and ↑ hand function with MHQ compared with control group ($p < 0.05$). – No significant difference in AROM of PIP joints, grip strength, BSHS, JHF, and FIM between groups. – No adverse effects reported.	Dynamic MCP joint flexion orthosis (Tx) VS no orthosis (Control) 1) **AROM**: ES calculated for average of 2nd – 5th **MCP** AROM right= 1.10 left= 1.37 AROM: ES calculated for average of 2nd – 5th **PIP** AROM right= 0.37 left= 0.39	2

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Table 2 – (continued)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
							2) **Hand function** (MHQ): 0.93 3) **Grip strength:** right hand= 0.16 left hand= 0.22 4) **QoL** (BSHS): 0.09 5) **5) ADL** (FIM): 0.19	
Covey et al. [38]	RCT	n = 10 (20 hands) Mean age = 45 y old TBSA= 13–61% All 20 hands received early excision and grafting of > 50% of the dorsal hand surface. Each participant had one hand in the control group and one hand in the Tx group.	Continuous passive motion (CPM) device – One intervention	1) Total AROM (TAMs) (using goniometry) obtained by adding the MCP, PIP and DIP flexion and subtracting any extension limitations for each finger. Impaired TAMs were defined as < 220°. 2) Other: Pain (0–10 VAS)	– **Control group**: Received "conventional hand therapy" 2x/d for 30 mins with active, active-assisted and passive ROM exercises performed by an experienced burn therapist. – **Tx group**: Received PROM via CPM device for 2hrs/d, increasing 1 hr/d for a maximum of 8hrs. Time of initiation not described. – **Both groups**: patients were discontinued from the study when their TAMs remained > 220° for 48hrs.	– No statistical analysis provided. – 8 hands (80%) in the control group and 8 hands (80%) in the Tx group regained TAM of > 220° on average of 9 days (3–22 days) after initial Tx. – 2 hands (20%) in each group that sustained tendon damage remained impaired at discharge. Both groups reported minimal pain during exercise. – No hands suffered graft loss attributable to ROM by either the therapist or the CPM device.	Not possible to calculate ES since SD not provided	2
Dewey et al. [14]	CC-retro	n = 71 Mean age = 39.6 ± 13.6 y old Mean TBSA = 5% (1.5% being hands) All hands	Early range of motion (EROM) – One intervention	1) ROM-combined MCP, PIP and DIP joint flexion (goniometry) (AROM presumably) 2) Edema (figure-of-eight technique)	– **Control group** (non-EROM): Wore a resting hand splint fitted in the post-anesthesia care unit. Dressings and splint remained in place for 3–5 days postoperatively. ROM was then initiated. – **Tx group** (EROM): Patients received EROM for an average of 30 min on post-op days 1 and 2. At the	– More EROM patients achieved active full-composite digital flexion by initial outpatient follow-up (92.6%) compared to the control group (68.2%) ($p < 0.05$). – Hand edema did not significantly differ	Not possible to calculate ES since SD not provided	4

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		underwent autograft		3) Other: Graft loss	beginning of EROM session, the splint, secondary dressings, and silver glove were removed. Active, active-assisted, and passive ROM were then directed by the burn therapist. ROM exercises were performed starting in proximal joints, moving distally.	between groups at any time point. – 8.8% of hands in the EROM group experienced graft loss and 5.9% in the control group, but none required additional grafting (non- significant difference)		
Dewey et al. [53]	SCD	n = 1 47 y old male TBSA = 34% Mechanism of injury: blast Full thickness burns to both hands dorsal and palmar, R axilla, arm, and forearm, back, buttocks, and bilateral thighs and legs. Partial thickness burns to head. R dominant hand with partial thumb amputation.	Thumb opposition splint with usual care (described) – Combination of interventions	1) Patient perceived disability (DASH) and level of impairment (Greenleaf EVAL with American Medical Association (AMA) impairment score)	– Daily IP therapy and OP therapy 5 x/52 after discharge. During 77 days of hospitalization received 200 Tx sessions and attended 216 appointments as an OP over 1 yr (see article for details on general IP and OP Tx modalities). – After 3 m of OP Tx and no significant functional improvement, a thumb opposition splint was fabricated as the patient's primary complaint was his inability to use his R hand due to the short length of the thumb (main intervention studied). The opposition splint was fabricated using low temperature thermoplastic materials and foam was placed distally on the volar portion to increase friction and improve pinch during functional use (see article for splint template).	– No statistical analysis provided. – Patient's initial DASH score was 65 at discharge from hospital 3 m later was 78. – Difference between DASH scores with and without using the splint were 25pts (↑ of 60%) at 3 m posthospital discharge, 16pts at 6 m, 10pts at 8 m, and 12 at 15 m (final DASH score was 32 with splint). – Several specific ADLs were self-reported to be noticeably enhanced with the use of splint (ex: turning a key, meal preparation, making a bed, etc.) – Patient's UE contribution to total body impairment was 70 upon splint fabrication, 63 at 6 m follow-up, 69 at 8 m follow-up, and 66 at 15 m follow-up.	N/A	4
Edgar et al. [45]	CS	n = 14 Mean age = 29.86 y old Mean TBSA	Rehabilitation (general) – Combination of interventions	1) Grip strength (Dynamometer) 2) Patient perceived	On average, the Bali survivors received 50.4 Tx sessions, for a total of 1730 min of contact time/patient. They received therapy daily during their IP and OP care	– 12 participants attended OP PT sessions regularly for 3–6 m. 6 m after discharge, only 2/14	N/A	4

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		= 33.71% Mean LOS: 22.4 days ± 19.93 (12–86)		physical function and QoL (BSHS)	according to their needs. The following treatments were provided: Education, hand therapy, daily gym strengthening and fitness, joint mobilizations, self-exercise programs and positioning regime for ICU. OP frequency of attendance was individually discussed and adjusted to accommodate return to work and regular activities.	patients remained in regular therapy. – Male grip strength ↑ until 12 m after discharge, but the mean grip strength was below normative data at all time points. Grip strength means for women exceeded the 95%CI for population norms by 6 m and plateaued at that time. At all time-points, L and R grip strength in women was not significantly different from norms. – BSHS scores in the physical and general abilities significantly ↑ from discharge and plateaued at 6 m. Group mean dysfunction level of 7.4% (95% CI of 6.0, 8.4%) at 6 m and 8.5% (95% CI of 5.8, 11.2%) at 12 m was not significantly different to published burn population BSHS norms.		
Edwick et al. [26]	RCT	n = 100 (68 males) Mean age = 40.1 ± 13.8 y old Mean TBSA= 0.51 ±- 0.96% Group 1 (Cylinder wrap): n = 33 Group 2 (Spiral wrap): n = 33 Group 3	Compression (Adhesive compressive wrap) – One intervention	1) AROM-composite finger flexion (cm); thumb opposition (Kapandji score); hand span: distance between thumb and pulp (cm); wrist flexion and extension (goniometry)	**Group 1** (Cylinder wrap): 10 cm applied as a cylinder from distal to proximal and pinched on dorsum of fingers. Another 10 cm applied in spiral with 50% overlap from hand to mid-forearm **Group 2** (Spiral wrap): 2.5 cm Coban applied to the fingers with 50% overlap, and a figure-of-eight application using 5 cm Coban to the hand and 7.5 cm Coban from the wrist to the forearm **Group 3** (Compression glove: sized accordingly): compression applied for 2.11 ± 0.40 days (range 1–3 days).	– Both methods of applying Coban were significantly superior to the compression glove for ↓ hand edema. – No difference in edema reduction between the two methods of Coban. – Nonsignificant improvement in hand composite flexion (P = 0.467) and wrist extension between	Not possible to calculate ES with Cohen's d, since no SD was provided. However, mean difference with 95%CI was provided for AROM measures in this article.	2

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		(Compression glove): n = 34		2) Edema-Bioimpedance spectroscopy (BIS) 3) Hand function (QuickDASH) 4) Other: Pain (VAS)	– Each application of latex-free Coban was applied at an estimated 50% of full stretch. 3 patients had compression applied for 1 day, and 13 patients remained in compression for 3 days. – All patients received a standardized and individualized home exercise program of active tendon glide exercises and performed finger abduction followed by composite finger flexion into a complete fist (10 x/h when awake). At rest and sleep, encouraged to elevate the affected hand above the level of the heart.	sessions (P = 0.310) (ceiling effect). – Hand span and wrist flexion ROM ↑ significantly between sessions for all 3 groups. – Nonsignificant ↓ in pain (P = 0.153), while the QuickDASH ↑significantly between sessions (P < 0.001, CI −15.2 to −8.52). – Thumb opposition, hand span, wrist flexion, and QuickDASH ↑ significantly for all compression methods compared to baseline. – Adverse effects: Removed compression due to ● numbness (n = 4) ● restricted movement (n = 4, 3 from spiral group, 1 from cylindrical group) ● malodor (n = 1, cylindrical group)		
Elsherbiny et al. [27]	RCT	n = 60 (58 participants with bilateral hand burns) Age range: 21–59 y old Control group: n = 30; Mean TBSA= 28.3% ±- 7.2 Tx group: n = 30; Mean TBSA= 27.5% ±- 11.0	Burn educational and training rehabilitation program – Combination of interventions	1) Burn health knowledge questionnaire 2) Patient perceived physical function and HRQoL (BSHS-B)	– **Control group**: received routine PT and rehabilitation at the burn center (no frequency information provided). – **Tx group**: received routine rehabilitation and the newly designed educational rehabilitation program including an educational component and training component performed for 45–60 min during 6 sessions. The educational part consisted of: general knowledge about burns, rehabilitation modalities and healthy lifestyle (Lectures, role-playing exercises, group discussions and real-life demonstrations; a burn rehabilitation booklet was given to all	– Knowledge scores of the Tx group were statistically higher than the knowledge scores of the control group at all program phases (1 m, 3 m). – Patient perceived physical function and HRQoL scores measured by the BSHS-B showed significant improvements at 1 m and 3 m and after implementation for the Tx group. Patient	Educational rehabilitation program and usual care (Tx) VS Usual care (Control) 1) **Level of burn health knowledge**: 1 m: 3.55 3 m: 3.50 2) **Patient perceived**	2

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
					participants). The training part consisted of anti-contracture positioning, therapeutic exercises and massage therapy training -Each participant was monitored daily until discharge and received regular phone calls after discharge for 3 m to ensure adherence to treatment plan.	perceived physical function and HRQoL scores of the control group also significantly improved over time, but their mean scores were significantly lower than the Tx group scores at the end of the study (3 m).	**physical function and QoL** (BSHS): 1 m: 3.00 3 m: 2.00	
Ghalayini et al. [50]	CO	n = 10 Median age = 34.5 y old TBSA: 0–10% (n = 6); 11–20% (n = 3); > 20% (n = 1)	OT for acute inpatients – Combination of interventions	1) Patient perceived disability (QuickDASH) and functional status and recovery (FAB)	– Patients received a mean of 30 min /day of IP OT (no OP rehabilitation, presumably). – These sessions included interventions such as: Edema management, protection of intrinsic musculature integrity of the hand, anatomical alignment of hand structures, protection of cutaneous and subcutaneous structures, counter contractile forces, promotion of AROM, encouraging patients in self-care independence, planning for safe and timely discharge, custom-molded splint(s) to maintain affected hand joints in safe position, gentle PROM of wrist and hand joints and prescription/supply of aids and equipment to facilitate self-care.	– -Patients were evaluated at T1 (just prior to discharge), T2 (3 m post-discharge) and T3 (6 m post-discharge). – -Most patients reached a ceiling score of 35 on the FAB at 3 months. – -Significant changes in QuickDASH scores were obtained between all time points. The change in score of the QuickDASH between T1 and T2 indicated that those who sustained a burn that involved the first web-space of the hand experienced slower functional recovery ($p < 0.05$). No other factors examined were significantly associated with scale or speed of recovery. For the QuickDASH, the median score changed between T1 and T2 accounted for 55 of the total 57 point score change between T1 and T3. Thus, recovery occurred most substantially within the first 3 m post discharge.	N/A	3

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Table 2 – (*continued*)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
Gittings et al. [28]	RCT	n = 48 Median age = 24–43 y old Median TBSA (IQR)= 14 (9–20)% Control group: n = 25 (60% had hand burns) Tx group: n = 23 (65% had hand burns)	Resistance training (RT) – Combination of interventions	1) Grip strength (Dynamometry) 2) Edema (Bioimpedance spectroscopy) 3) Patient perceived disability (QuickDASH) and perceived physical function and QoL (BSHS-B)	– **Control group**: received standard PT (respiratory care, extensive mobilisation from the day of injury and all exercise other than RT including stretching, AROM, balance and postural exercises, use of the treadmill, stationary bike and upper limb cycle ergometer) – **Tx group** (resistance training group = RTG): received standard physiotherapy and a RT program 3x/w for a 4w period. The RT sessions were completed in place of standard PT for that day's treatment. RT session composed of bilateral bicep curls, lateral deltoid fly, overhead shoulder press, knee extensions and leg press using both free weights and a cable weighted multi-gym. The intensity of RT exercise was prescribed at 70% of maximum voluntary isometric contraction for that day, thereby titrating the training load to reflect current capacity. Each exercise was performed for 3 sets of 8–12 repetitions.	– Muscle strength results combined multiple muscle groups, so results specific to hand strength could not be extracted. – No difference in the change of edema over time between the control and Tx after adjustment for baseline edema, TBSA and gender. – No difference in the odds of recovery across time between the Tx and control group based on the total BSHS-B total score (OR = 0.991, p = 0.802). – For every ↑ of 1w, the Function domain of the BSHS-B demonstrated a further 20% increase in the odds of recovery in the Tx group, compared with the control (OR = 1.21, p = 0.017). – For the QuickDASH, the Tx group demonstrated a significantly greater rate of recovery compared to the control group (IRR 0.770; 95% CI 0.670–0.886; p < 0.001). The control group (Median (IQR): 6.82 (0.0–20.45)) had worst scores than the Tx group at 12w (Median (IQR): 2.27 (0.0–2.27)). At 26w, both groups had a median score of 0.	Not possible to calculate ES with Cohen's d since no SD was provided. However, the study provided some OR and IRR: see results section)	2

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Table 2 – (continued)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
Grisbrook et al. [41,63]	CC	n = 18 Mean age = 39 ± 8.51 y old Control group: n = 9; No burns Tx group: n = 9; Mean TBSA= 42% ±- 18.38; Mean time since injury = 6.56 y ± 3.68	Exercise training: Interval training and resistance exercise components – One intervention	1) Patient perceived level of functional impairment (QuickDASH) 2) Other: QoL (BSHS-B and SF-36)	– **Control group**: Healthy control group. – **All participants** (Tx + control) completed a 12-week individualised goal-orientated, strength and endurance based exercise programme under the supervision of a qualified exercise physiologist. 12-week program: 3x/52 for 80 min. Functional goals were defined for each participant using the Canadian Occupational Performance Measure (COPM). – **Tx group**: the specific interval aerobic and resistance training protocol was described by Grisbrook et al., 2012[63]: Participants warmed up on the treadmill for 5 min and stretching was performed at the completion of each session. The interval training consisted of 30 min of walking/ jogging performed on a treadmill. Participants were instructed to initially walk/jog at a high intensity workload that equated to 85% of their individual HR max (220-age), for 120 s, and then to reduce this intensity to a level that represented a low/moderate intensity workload (65–70% HR max) for 120 s, with this sequence being repeated over a 30 min period. Exercise intensity was gradually increased every week. Resistance exercise training targeting muscles specifically involved in each participant's goals. Training commenced at a load of 50–60% of each individual's assessed maximum and participants performed 3 sets of 10–15 repetitions. Resistance exercises progressed to the use of machine weights, followed by free weights. The final phase involved the participants performing their	– Tx group ↑ their QuickDash scores from baseline in response to training, but the improvement was not significant. – Control participants significantly ↑ their QuickDASH score ($t(8) = 2.42$, $p = 0.042$) over the training period. – No significant difference between the Tx and control groups QuickDASH scores at completion of exercise training. – Pre and post-Tx scores: Tx group showed a significant ↑ in only the work domain on the BSHS-B ($t(8) = 2.43$, $p = 0.041$). – Pre exercise: control group had significantly better BSHS-B scores for the hand function, work, heat sensitivity, treatment regimens and body image categories. – Post-exercise: control group only had significantly better work, heat sensitivity and body image categories on the BSHS-B. Tx group showed a non-significant improvement in total BSHS-B score. – Post-exercise: both Tx and control groups showed significant	Pre exercise training VS Post exercise training 1) **Level of impairment** (QuickDASH): 0.27 2) **QoL**: Not possible to calculate ES, because compared to healthy controls	4

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Table 2 – (*continued*)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
					occupational performance goals, incorporating resistance into the activity for strength and endurance gains.	improvement in physical and mental health categories on the SF-36 and the SF-36 total scores.		
Guillot et al. [29]	RCT	n = 14 Mean age = 47.08 ± 13.92 y old All participants had deep second-degree to third degree burns without grafts Control group: n = 5 Tx group: n = 9	Motor imagery (MI) – One intervention	1) AROM (goniometry) and thumb opposition (Kapandji score) 2) Other: MI vividness score using a 6-point Likert scale (1 =no image; 6 = very clear image); Mental chronometry (the temporal congruence between MI and motor performance times); Patient questionnaire of satisfaction	– **Control group**: All participants spent equivalent time to perform usual rehabilitation including active and passive manipulations. The control group performed neutral activities during the equivalent time that the Tx group performed MI. – **Tx group**: participated in 5 supervised MI sessions in a 2w period. 2 sequential motor tasks were performed during the MI sessions: the spellcaster task (maximal wrist extension with a clenched fist followed by wrist flexion while opening finger) and finger to thumb opposition task.	– Tx group had significantly better finger-to-thumb opposition, finger flexion and wrist extension compared to the control group ($p < 0.05$). – Tx group: duration of the MI did not change across the 5 sessions. All patients indicated that MI may have contributed to the enhancement of motor functions, but reported having difficulties in forming the mental images of movement.	MI + usual care VS usual care 1) **AROM**: finger-to-thumb opposition= 0.21; finger flexion = 0.77; wrist extension during spellcaster movement = 0.78; wrist flexion during spellcaster movement = 0.09	2
Hwang et al. [46]	CS-prosp	n = 24 (36 burned hands, 140 web space burn scars) Tx group: Mean Age= 35 ± 10 Average hand burn size: TBSA = 3 ± 1% All participants had dorsal hand burns, 12 patients had bilateral hand burns, 12 patients had one burned	Webspace pressure insert – One intervention	1) AROM- Measurement of the dorsal slant of web space (goniometry)	– Otoform-K was contoured to each web space to form custom-made web-space inserts. The inserts were secured with silk socks and then the pressure glove was applied. Patients were instructed to wear these inserts according to their tolerance level and then gradually increase wearing time for as many hours each day as possible. The inserts were adjusted progressively to be firmer, thicker, and larger in diameter. – Termination use of inserts was determined by two factors: 1) evidence of scar maturation (ie, resolution of scar hyperemia and softening of the skin) and 2) no evidence of change in	– Mean dorsal slant angle of the 36 dorsal burn hands were significantly reduced for every web space after wearing the web space pressure inserts ($P < 0.001$). – Except for the first web space, significant difference was observed between the final dorsal slant and normal value (obtained in this study by generating normative dorsal slant values with 29 volunteers) for each of the second, third, and	N/A	4

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		hand. A group of 29 healthy volunteers (58 hands) were used to obtain normative unburned ROM of dorsal slant of web space for comparison.			the angle of dorsal slant for at least 3 consecutive measurements.	fourth web spaces ($P < 0.001$). Therefore, the first web space dorsal slant inserts showed best recovery compared to normative data. – Adverse effects: some participants presented with skin maceration, blistering, abrasions, and ulcerations that may have resulted from the wear. Some complained of numbness, pain, or functional restriction, especially while grasping and manipulating objects. It was noted that wearing web space pressure inserts restricts MP flexion motion.		
Joo et al. [30]	RCT	n = 57 Control group: Mean age = 41.69 ± 14.05 y old; Mean TBSA=27.38%±-20.65 Tx group: Mean age = 48.07 ± 8.14 y old; Mean TBSA=27.71%±-20.15	Virtual reality (VR) – One intervention	1) Hand function (JHFT, PPT and MHQ) 2) Grip and pinch strength (dynamometer)	– **All patients** received standard therapy for 4w (20 sessions for 60 min/d) compromised of: ROM exercises for the burned hand, strengthening exercises of the upper extremities, manual lymphatic drainage, and desensitization program for hypertrophic scars. – **Tx group** (VR) received 30 min standard therapy and 30 min VR-based rehabilitation. The RAPAEL Smart GloveTM (Neofect, Yong-in, Korea) system, which combined the use of an exoskeleton type glove and VR system, was used and operated by active hand movements.	– JHFT subtest scores for picking up small objects and simulated feeding in the VR group showed significant improvements, compared to the control group ($p < 0.001$ and $p = 0.04$). The subtest score for picking up small objects significantly ↑ in the VR group after intervention ($p = 0.01$). – No significant PPT changes between the groups for the affected hand, both hands, or assembly after intervention ($p = 0.74$, $p = 0.33$, and $p = 0.41$).	VR rehabilitation + usual care VS usual care 1) **Hand function**: (PPT)= 0.098 (MHQ)= 0.35 2) **Grip strength**=-0.53 **Lateral pinch**= 0.89 **Tip pinch**= 0.83	2

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Table 2 – (*continued*)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
						– MHQ subtest scores for functional ADL and patient satisfaction in the VR group showed significant changes, compared with the changes in the control group ($p = 0.003$ and $p = 0.001$). Significant difference between groups for the MHQ functional ADL, work, pain, and patient satisfaction scores ($p = 0.005$, $p = 0.04$, $p = 0.002$, and $p = 0.02$). – Significant improvements in the grip, lateral pinch, and tip pinch strength before and after intervention in the VR group compared to the control group ($p = 0.03$, $p = 0.002$, $p = 0.03$, respectively). – No significant differences in the grip, lateral pinch, and tip pinch strength between the two groups after intervention ($p = 0.13$, $p = 0.06$, and $p = 0.07$, respectively). – No participants experienced adverse effects.		
Kamal et al. [31]	RCT	n = 40 Age range = 18–40 y old Group 1 (dynamic): n = 20	Orthosis – One intervention	1) AROM- by radiological measurement 2) Grip strength (dynamometer) 3) Hand function (JHFT)	– **Group 1** (dynamic): modified dynamic MCP orthosis for 3 hr/d for 8w. – **Group 2** (static): static orthosis worn at night for 8w and AROM performed multiple times per day.	– AROM of MCP ($P < 0.003$), grip strength ($P < 0.001$) and hand function ($P < 0.001$) significantly improved post-Tx for both groups.	**Dynamic PRE VS Dynamic POST** 1) ES calculated for average	2

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		Group 2 (static): n = 20				– Between group comparison showed better results in Group 1 post-Tx for AROM ($P < 0.002$) and hand function ($P < 0.0001$) compared with Group 2. No difference in grip strength between groups post-Tx.	of 2nd – 5th MCP AROM = 4.01 2) Grip strength = 2.36 3) Hand function = 6.41 **Static PRE VS Static POST** 1) ES calculated for average of 2nd – 5th MCP AROM = 1.22 2) Grip strength = 2.01 3) Hand function = 1.60 **Dynamic post VS Static post** 1) ES calculated for average of 2nd – 5th MCP AROM = 2.70 2) Grip strength = 0.66 3) Hand function = 2.71	

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
Li et al. [32]	RCT	n = 60 Control group: Mean age= 35.5 ±- 12.59 y old; Mean TBSA = 15.80%± 18.59;- dominant burned hand = 56.7% Tx group: Mean age = 38.33 ± 14.10 y old; Mean TBSA=15.27%±- 17.34; dominant burned hand = 63.3%	Rehabilitation intervention model – Combination of interventions	1) Level of comprehensive health condition and QoL (BSHS-A)	– **Control group** (G1): conventional nursing and rehabilitation 5–7x/52 – **Tx group** (G2): Rehabilitation intervention model in 3 phases: 1) The acute phase (T1): started before basic wound healing approximately 1–3 days after admission: Establishing nurse-patient relationship, social support, health education, client-centered therapy for targeted psychological interventions: 2 psychological consultation sessions 30–50 min, passive hand movement: 10–15 min/session, 2x/day 2) Convalescence phase (T2): started at the onset of basic wound healing after skin grafting and lasted 4 w and it involved the training of patients in the rehabilitation room: Client-centered therapy or rational-emotive therapy: 2 psychological consultations 30–50 min, gradual sequence from passive to passive and active to active hand exercises. 3) Discharge phase (T3): Started 1–2 d before discharge from the hospital: Rational-emotive therapy for patients who still had issues, discussion about employment.	– Comprehensive health significantly improved in the two groups after the intervention period having a main effect on: comprehensive health ($F = 98.73$, $p < 0.001$) as well as for the subdomains: physical function ($F = 19.879$, $p < 0.001$), psychological function ($F = 72.180$, $p < 0.001$), social relations ($F = 12.957$, $p = 0.001$), and general health condition ($F = 38.368$, $p < 0.001$). – At T3: Tx group improved more compared to the control group. Significant differences in comprehensive health ($F = 46.880$, $p < 0.001$), physical function ($F = 15.326$, $p < 0.001$), psychological function ($F = 30.003$, $p < 0.001$), social relations ($F = 11.045$, $p = 0.002$), and general health condition ($F = 31.208$, $p < 0.001$) between the two groups.	Rehabilitation intervention model VS usual care at T3 1) **Comprehensive health** (BSHS-A): 1.36	2
Lowell et al. [54]	SCD	n = 1 59 y old male 56% TBSA flame injury. Bilateral full thickness burns to hands, face, and LE. Full-thickness dorsal burns to the hands were excised and	Compression (Adhesive compressive wrap) – One intervention	1) Edema-circumferential measurements (in inches) of both hands at the MCP, PIP, DIP and wrist joints using a standard tape measure.	– **Control group** (L hand): Wrapped in a standard gauze dressing – **Tx group** (R hand): After surgery, was wrapped in 3 M Coban self-Adherent Wraps. Coban and gauze dressings were changed every other day starting on post- operative day (POD) 3. One-inch Coban was used on the digits, and each digit was wrapped separately in a spiral pattern. Only the tips of the digits were exposed to	– -No statistical analysis provided. – -POD 3, measurable difference in edema between the Tx hand control hand, which increased until day POD 11. Control hand was wrapped in Coban on this day because of the	Not possible to calculate ES since no SD was provided	4

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		grafted. Grafts were located over all five digits of each hand up to the fingernails Control hand: L Tx hand: R (dominant hand)		2) AROM- total range of motion (TROM) of all joints measured (MCP, PIP, DIP and wrist) (goniometry) 3) Grip strength (dynamometer) 4) Hand function (nine-hole peg test)	allow for tip-to-tip prehension. The hand and wrist were wrapped in 2-inch Coban using a "figure eight" pattern. – Patient was engaged in therapy program involving both hands: positioning, passive stretching, AROM exercises, strengthening exercises, and functional exercises.	disparity in circumference. – -PODs 15 and 17 the amount of edema in both hands ↓ and the differences between the hands varied on each of these days. – -POD 17 the total AROM of the Tx hand was 74° and the control hand was 53°. Although the total AROM of the control hand ↑ from POD 17 to POD 24 and POD 31, the Tx hand maintained greater AROM through POD 31. – -Strength in both hands ↑ from POD 17 to POD 31. Tx hand improved from 35 lbs to 50 lbs to 61 lbs on PODs 17, 24, and 31, respectively vs 25 lbs to 26 lbs to 35 lbs for the control hand. – Nine-hole peg test (Average times) ● POD 17: Tx= 26 s; Control= 77 s ● POD 31: Tx= 20 s; Control= 32 s		
Mohaddes Ardebili et al. [33]	RCT	n = 60 Age range = 15–25 y old Control group: Mean age = 28.23 ± 9.81 y old Tx group: Mean age = 31.43 ± 8.91 y old	Patient education program on exercise therapy – Combination of interventions	1) Hand function (JHFT) and observational checklist to determine ROM of wrist and fingers	– **Control group**: received usual care. – **Tx group**: received an educational program: 1–2 individual education sessions and 2–3 group education sessions of 30–45 min The individual sessions were given 72 h after burn injury and discussed the importance, necessity, and effects of physical movements of hands, prevention of deformation and functional disorders, importance of adherence to Tx program.	– Intervention group demonstrated statistically significant improvements in ROM (ability to bend R wrist (P = 0.001), bend L wrist (P = 0.019), rotate R wrist (P = 0.005), rotate L wrist (P = 0.01)) and hand function (write, ability to lift objects with R hand	Not possible to calculate ES since no SD was provided	2

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		All patients were R-handed and had at least two burned hands			During group session patients were trained about necessity of performing hand exercises and how to conduct them.	(P = 0.006) and L hand, eating with spoon with R hand (P = 0.001) and L hand (P = 0.002), ability to arrange small objects with R hand (P = 0.000) and L hand (P = 0.034), displace large light objects with R hand (P = 0.006) and L hand (P = 0.01) and arrange heavy objects weighing 1lbs with R hand and L hand (P = 0.002)) compared to the control group after intervention. – No statistically significant differences between groups for turning objects with R hand (P = 0.26) and L hand (P = 0.17) and ability to write with L hand (P = 0.22)		
Nam et al. [57]	MCD	n = 3 Case 1: 21 y old; TBSA = 47%; L hand contractures Case 2: 37 y old; L hand 3rd and 5th finger contractures due to crush injury under hot press machine. Case 3: 38 y old; Deep second- to third-degree electrical burns	Orthosis: 3D-printed finger splints – One intervention	1) AROM MCP, PIP and DIP (goniometry presumably) 2) Measure of physical disability (MBI)	– **Case 1**: A 3D-printed finger extension splint was applied to her 2nd and 5th fingers to prevent flexion contracture of finger joints and angulation deformity. Worn 2 h/d. – **Case 2**: A 3D printed corrective finger extension splint was applied to her 3rd and 4th fingers to prevent flexion contracture. – **Case 3**: A static molded plastic splint was applied (right index) for the mallet finger. However, he showed poor compliance due to an irritation of the flapped dorsal skin underneath the splint. The splint was changed to the 3D-printed soft material finger extension splint to minimize the skin irritation.	– No statistical analysis provided. – Case 1: Improvement in 3rd, 4th and 5th digit MCP, PIP, DIP ROM (30–40° of flexion with full active finger extensions vs. 0° AROM pre-intervention) and performance in ADL with MBI ↑'d from 84 to 91. – Case 2: Slight improvement of ROM of 3rd, 4th and 5th MCP flexion, PIP flexion, and PIP extension. Able to make a fist, perform all pinch motions and	N/A	4

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Table 2 – (continued)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		involving both of hands				oppositions with all five fingers. Performance in ADL remained constant with a total MBI of 95. – Case 3: Improvement in 2nd finger position. The digit regained a neutral position with the 3D splint vs. DIP joint fixed to 45° pre-intervention.		
Neeman. [56]	MCD	n = 2 Case 1: 57 y old; TBSA = 5%; second degree burns on both hands and wrists Case 2: < 18 y old = excluded from this review	Orthokinetic Orthosis – One intervention	1) AROM (goniometry and fist closure in cm) 2) Grip strength (dynamometer)	– **Case 1**: Orthokinetic orthosis positioned over the major bulk of the muscle group selected to facilitate its contraction, while an inactive field covers the antagonists. R hand Tx consisted of an intensive time-series design A1-C1-A2-C2-A3-B1-A4 (A1 = pre-treatment; C1 = placebo - application of the orthokinetic cuffs with two layers of elastic bandage on the forearm; C2 = application of the orthokinetic cuffs with two layers of active over the wrist/finger extensors and inactive field over the wrist/finger flexors; A2-A3 = non treatment phases; B1 = application of the same cuffs as in phase C2 but rotated at 180°). Time of each phase: 3 min Therapy protocol during each phase: finger flexion-extension, making a fist, and using a foam hand exerciser and Theraputty for strengthening. -**Case 2**: N/A	– No statistical analysis provided. – Improvement in post-treatment active flexion of 2nd, 3rd, 4th and 5th digits. – No improvement of thumb active flexion. – Slight ↑ of grip strength in phase C2 and substantial ↑ in phase B1 with carry-over 24 h later.	N/A	4
O'Brien et al. [16]	CC	n = 23 Age range = 20–28 y old TBSA range: 1–49% (22.9% ± 16.6) Subjects served as their own	Compression (gloves) – One intervention	1) Hand function (JHFT) 2) Other: patient rating of difficulty of JHFT tasks using both gloves, patient	Subjects were assigned randomly to standard burn pressure glove (SPG) group or the NewYork-Presbyterian Dexterity Glove (NYPDG) group for the first trial. Subjects were instructed to gradually ↑ glove wear from 4 h to 23 h during a 6 d time frame. Once the 23 h/d schedule was attained, subjects were instructed to wear	– Significantly better results reported with the NYPDG glove for all outcomes: JHFT 21 s faster on average ($P < 0.01$), the Likert scale revealed tasks were easier to perform	Not possible to calculate ES since no SD was provided	4

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Table 2 – (*continued*)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		control (received gloves in random order)		rating of difficulty of 15 pre-defined fine motor ADL tasks, patient rating of difficulty of 11 pre-defined gross motor skills	the glove during all daily activities. After 7–10 days, subjects returned for evaluation and fit for the remaining glove (same wearing regime as the first glove).	($P < 0.01$), fine motor ADL and gross motor ADL where less difficult to complete ($P < 0.04$; $P < 0.01$). – The order in which the subjects received the gloves (order effect) did not statistically influence any of the outcomes. A significant period effect was found for the Jebsen test scores only.		
Omar et al. [34]	RCT	n = 30 (35 hands) Age range = 20–28 y old TBSA range = 20–35% Control group: n = 15 (18 hands) Tx group: n = 15 (17 hands)	Electric stimulation – One intervention	1) ROM – total AROM of fingers (TAM) (goniometry) 2) Edema (Volumetry) 3) Hand function (Patient's ability to perform 12 tasks)	– **Control group**: usual care. Therapy protocol included active free and active assisted ROM exercises 2–4 × /d. – **Tx group**: electric stimulation +usual care. Electric stimulation consisted of alternating stimulation of the median and ulnar nerve at 120 PPs (pulse-per-second) for 30 min (no frequency information provided).	– Significant improvement in TAM, edema, functional results, and duration of recovery for the Tx group over time. Values of improvement were better in the Tx group compared to the control group for all 3 outcomes.	ES +usual care VS usual care 1) **AROM**: 4.33 2) **Edema**: 1.71	2
Paratz et al. [40]	NRS	n = 30 Age range = 19–69 y old TBSA range = 20–70% (42.9% ± 13.3) Control group: n = 14; 44% hand burns Tx group: n = 16; 88% hand burns	Exercise program – Combination of interventions	1) Hand function (QuickDASH) 2) Grip strength (dynamometer) 3) Other: Health related QoL (BSHS-A)	– **Control group**: Performed a self-management exercise program: stretching program monitored once a week and a referral provided to local therapists for an exercise program. – **Tx group**: Received an intensive exercise program: stretching program and supervised high-intensity (80% maximal heart rate and 70% three repetition maximum) combined aerobic or resisted exercise program 3x/52 for 60 min x 6w. They were encouraged to continue a similar program from 6w to 3 m without supervision.	– Significantly greater improvement in the intensive exercise group than the control group at 3 m for hand function: QuickDASH (5.7 vs. 23.98, p = 0.001), health-related QoL: BSHS-A (7.64 vs. 35.13, p = 0.004) and grip strength: R hand (42.86 vs. 14.86, p = 0.001) and L hand (7.26 vs. 16.83, p = 0.04).	Exercise program VS self-management exercise program 1) **Hand function** (QuickDASH): 6w= 0.36 3 m= 0.50 2) **Grip strength:**	3

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
							R hand: 6w= 0.25 3 m= 0.07 L hand: 6w= 0.22 3 m= 0.002 3) **Health related QoL** (BSHS-A) 6w= 0.36 3 m= 0.56	
Park et al. [51]	CO-retro	n = 42 Control group: n = 20; Mean age= 45.85 ±- 5.73 y old; Mean TBSA=36.60%±- 14.36 Tx group: n = 22; Mean age= 45.86 ±- 8.51 y old; Mean TBSA=31.91%±- 19.88	Compression (compression bandages) – One intervention	1) Edema (figure of eight in cm) 2) ROM- AROM of MCP and PIP joints (goniometry) 3) Grip strength (dynamometer) 4) Hand function (JHFT) 5) Skin outcome: skin thickness (ultra-sound) 6) Other: pain (VAS)	– **Control group**: Received 4w of intensive rehabilitation (PROM exercise, ADL training, manual lymphatic drainage, and skin care). – **Tx group**: Receive a modified hand compression bandage avoiding the PIP and MCP joint, applied to the patients by PT 6 d/w for usual care. The bandage consisted of: 1 in. bandage gauze to wrap from the wrist to all the 5 fingers, starting at the fingertip to the MCP joint. Thereafter, a 1 in. short stretch bandage was used to wrap all 5 fingers, excluding the MCP and PIP joint. Last, bandage was performed from the MCP joint to the wrist, using a 3 in. short stretch bandage.	– Significant time effect ($p < 0.05$) and time×group (reciprocal action) effect ($p < 0.05$) for edema, skin thickness, pain, and all MCP AROM. Grip strength, JHFT, and all PIP AROM, showed significant differences in accordance with the time effect ($p < 0.05$), however, there was no reciprocal action effect ($p > 0.05$).	Modified hand compression bandages + usual care VS usual care 1) **Edema**: 4w= 0.66 4 m= 0.10 2) **AROM**: ES calculated for the average of 2nd – 5th **PIP and MCP at 4 m** PIP= 0.24 MCP= 1.77 3) **Hand strength**: 4w= 0.11 4 m= 0.25 4) **Hand function (JHFT)**: 4w= 0.27 4 m= 0.031	3

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Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
							5) **Skin thickness**: 4w= 0.86 4 m= 0.17 6) **Pain:** 4w= 1.28 4 m= 1.94	
Pruksapong et al. [35]	RCT	n = 12 (16 hands) Mean age = 27 y old Hand burns with second- and third-degree burns requiring a skin graft and secondary intention for the superficial burn. The dorsum of each hand was divided in 3 areas and each area received different Tx (radial and ulnar randomly assigned: Silicone gel sheet or silicone gel: central: control).	Silicone combined to pressure garment – One intervention (The silicone + pressure was considered to be one intervention)	1) Scar outcome (VSS and POSAS)	– **Control** (no Tx; central): Pressure garment (PG) only. – **Treatment A** (Silicone gel): Silicone gel was randomly assigned to radial or ulnar side of dorsum of hand. 0.25 ml of the gel was applied to 5 cm ^{2} of scar surface area and then left to dry before applying a customized PG glove – **Treatment B** (Silicone gel sheet): A silicone gel sheet was cut and fit for the burned wound lesion, not extending beyond the knuckle, and applied to the other side of healed hand burn in a randomized sequence – All groups wore their assigned Tx for 23hrs/d, except during bath/shower.	– No significant differences in all VSS parameters between the 3 groups. Three of 6 POSAS parameters (stiffness, thickness, and irregularity) showed significant differences among the 3 groups ($P < 0.05$). Silicone gel and silicone gel sheet combined with PG improved the stiffness outcome at 8- and 12-weeks follow-up; however, there was no significant difference between the 2 materials. Thickness significantly improved when the silicone gel group was compared with the control group at 2, 4, and 8 weeks follow-up. Scar irregularity showed significant improvement at 2, 4, 8, 16, and 20 weeks in both silicone materials combined PG groups when compared with PG alone. – No statistical difference between both silicone	Not possible to calculate ES since no SD was provided	2

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Table 2 – (*continued*)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
						groups when observed at the 1-year follow-up		
Puri et al. [47]	CS-prosp	n = 42 (90 joint contractures) Mean age = 28.7 (2–70) y old	Serial static orthosis – One intervention	1) ROM (presumably goniometry) Percentage of movement recorded at weekly intervals. Time to plateau noted. 2) Other: need for reconstructive surgery (RS)	Custom fabricated low temperature thermoplastic (LTTP) serial static orthoses worn continuously (removed only for exercise, scar massage or needed activities). Time of orthosis initiation not noted, but contracture already present. Therapy protocol included scar massage, passive stretch 2 × /d for 20–30 min	– Mean improvement in contracture 41.2 ± 30.3° for patients with thermal burn and 31.8 ± 26.8° for patients with electrical burn ($p = 0.005$). – Mean time to achieve ROM plateau was 23.6 ± 3.2 days for all groups. No difference in contracture improvement between males and females ($p = 0.447$) or in contractures within 1 y or greater than 1 y ($P = 0.74$). – Greatest improvement was seen in MCP joint (49.6 ± 31.3°), elbow (44.28 ± 27.14°), PIP (34.5 ± 25.1°), and DIP (27.3 ± 18.8°), all statistically significant. Complete correction of contracture was achieved in 28.7% of thermal burns. Need for RS was eliminated in 12.6% of cases.	N/A	4
Pusineri et al. [55]	SCD	n = 1 54 y old male	Virtual reality – One intervention	1) ROM- AROM of MCP, PIP and DIP joints (goniometry presumably) 2) Grip strength (dynamometry) 3) Hand function (Hand function disability scale in the Technobody	Patients received 1x/m, 5 OTsessions in the form of Virtual Reality (~ 20 min/ session + traditional rehabilitative treatment 1x/d for 6 m and then 2x/52 for 12 m: motor re-education (active-assisted kinesiotherapy and stretching associated to scar massage), ultrasound therapy at 6 m post-burn, 3 sessions of extracorporeal shock wave therapy at 12 m post-burn.	– No statistical analysis provided. – Gradual improvement in mobility, grip strength (0 kg pre to 28.5 kg post Tx) and hand function. The patient gradually recovered an almost complete fist and ↑'d manual coordination and speed (results obtained during VR tasks), restoring his	N/A	4

(continued on next page)

Table 2 – (continued)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
				Motion Analysis® 1.0 VR software)		independence in ADL (hand function disability scale improved from 90/90–3/90).		
Riaz et al. [36]	RCT	n = 80 Group 1 (Ultrasound therapy): n = 40; Mean age = 26.65 y old Group 2 (Paraffin wax bath therapy): n = 40; Mean age = 24.67 y old	Ultrasound therapy VS Paraffin wax bath therapy – Combination of interventions	1) ROM- PROM for IP joint extension (goniometry)	– **Group 1** (Ultrasound therapy): ultrasound, stretching exercise and massage. Ultrasound therapy: frequency of 3 mHz for 5 min with pulsed duty cycle and power of 0.50–0.80 W/cm^2 (watt/centimeter square) applied in a circular manner over the scar contracture with a 1-cm diameter probe. – **Group 2** (Paraffin wax bath therapy): paraffin wax bath therapy, stretching exercise and massage. Paraffin wax therapy consisted of applying 10–14 layers of wax at a temperature of 42–44 °C by brush paint method, and the area was covered with a glove for 20 min (no frequency information provided). In both groups, a total of 3 sets of the stretching exercise with 5 repetitions each were performed by the therapist on each visit. Deep tissue massage on the scar and the surrounding skin was applied for 4–6 min, 6–8x/d by the patient.	– Group 1 displayed improvement in PROM with a mean increase of 4.97° (SD 0.94). – Group 2 showed a mean increase in PROM of 9.37° (SD 4.41) ($p < 0.005$). – Paraffin wax therapy with stretching exercises and massage were more effective as compared to ultrasound therapy with stretching exercises and massage for the management of post-burn contractures of small joints of the hand.	Ultrasound therapy PRE VS POST Ultrasound therapy 1) **PROM**: 0.36 Paraffin wax therapy PRE VS POST paraffin wax therapy 1) **PROM**: 0.80 ES of parrafin VS Ultrasound therapy 1) **PROM**: 1.38	2
Richard et al. [37]	RCT	n = 6 Age range = 26–53 y old Mean TBSA = 44% Each patient was their own control: alternated treatment approaches	Static wrapping VS passive exercises – Combination of interventions	1) ROM- AROM of MCP and PIP joints (goniometry presumably)	– **Static wrapping group:** Patients were wrapped with 3-inch elastic bandage into a full mitten configuration. Pressure was applied to ↑ finger flexion for 10 min. Tx approach was alternated on each hand – **Passive exercise group**: Index, middle, ring and small fingers passively ranged. PROM progressed from isolated single joint motions to full flexion or mass grasp (no frequency information provided).	– MCP and PIP joint flexion mean ↑ 7.46° and 4.28° respectively with passive exercises and 2.65° and 9.68° with static wrapping. – Percentage of improvement relative to normal flexion values for the MCP and PIP joint with passive exercise were 8.53% and 3.69% and 2.92% and 8.09% with static wrapping respectively.	Not possible to calculate ES since no SD was provided	2

(continued on next page)

Table 2 – (*continued*)

Citation	Desi-gn	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
						– All differences were statistically significant (p < 0.001).		
Schneiderr et al. [52]	CO-pros	n = 11 Mean age = 52 y old Mean TBSA = 41%	Rehabilitation (general) – Combination of interventions	1) Hand function (JHFT)	Inpatient rehabilitation performed by OT and PT 3x/d, 5 d/52 tailored to each patient: scar massage, ROM, strengthening, functional mobility, gait training, balance activities, fine motor activities, splinting, compression garment treatment and ADL.	– Patients' discharge JHFT scores were below normative data, but significantly ↑'d from admission. – Mean JHFT times ↑ by 42% (p < 0.037) in the dominant hand and 33% (p < 0.009) in the non-dominant hand from admission to discharge.	N/A	3
Shi et al. [42]	CC	n = 28 Age range = 29–44 y old Hand TBSA range = 4.74% ± 0.43 Patients were dependent the eating activity due to UE limitations.	Adaptive equipment: forearm pronation-assist tableware – Combination of interventions	1) Measure of physical disability (MBI) 2) Other: Patient satisfaction (VAS), duration of lunch (time), weight of food spilled.	– Each patient was their own control: compare MBI with no auxiliary cutlery or wearing the ADL universal cuff versus wearing the forearm pronation-assist tableware. – In the first 2 tests (lunch) there was no auxiliary tableware. The next 4 days, each patient used a random lottery for the forearm pronation-assist table ware or for the ADL universal cuff to determine which auxiliary tableware was used for lunch. The same type and amount of food were tested in every test (lunch). The forearm pronation-assist tableware was customized to each patient by using LTTP.	– Use of forearm pronation-assist tableware significantly ↓ dependence on others' help (MBI's eating item) (p < 0.05) and subjects were more satisfied with their eating activity (VAS) (p < 0.001) compared to when eating with no auxiliary cutlery or wearing the ADL universal cuff.	Not possible to calculate ES since no SD was provided	4
Weinstock-Zlotnick et al. [48]	CS	n = 2 (3 hands) Case 1: 51 y old male; dorsal surface of both hands scald burns Case 2: 49 y old male; TBSA= 0.5%; Dorsal and volar R hand	Compression (comparing two types of pressure garment gloves) – One intervention	1) Hand function (JHFT) and self-reported ease of performance of 10 function tasks 0–5) 2) Grip and pinch strength (dynamometer and pinch meter)	– Participants received 2 types of pressure garment gloves, standard-pressure garment glove (SPGG=control) and pressure garment work glove (PGWG=Tx). Each individual selected which glove they preferred to wear first. Testing was separated by a period of 1–2w to ↓ the likelihood of a training effect.	– Grip and pinch strength and functional sensation were ↓ overall with the PGWG (significant). – However, better performance was noted with functional tasks involving gross and fine-motor movements (significant).	Not possible to calculate ES since no SD was provided	4

(continued on next page)

Table 2 – (*continued*)

Citation	Design	Sample	Treatment type	Outcome measures	Intervention	Results (+ adverse effects)	Effect size for intervention group for each outcome	Level of Evidence
		flame burns Each participant hand also served as its own control Both patients were R dominant		3) Other: Functional sensation (MPUT)	– **Participant A**: Hands 1 and 2 wore the same glove type during each trial week and were tested on the same occasion. – **Participant B:** only one hand wore the selected glove during each trial period.	– Unanimous participant preference for the PGWG.		
Wu et al. [39]	NRS	n = 16 Age range = 8–30 y old Mean TBSA = 63% Control group: n = 8; Mean TBSA=57.75%±-13.38 Tx group: n = 8; Mean TBSA=68.50%±-14.90	Virtual reality (Leap motion controller (LMC) – One intervention	1) Hand function (BSHS-B, QuickDASH, iADL and Barthel index) 2) ROM - AROM of thumb IP joint (ergometer) 3) Grip and pinch strength (hydraulic dynamometer and pinch gauge) 4) Scar outcome: scar thickness (ultrasound)	– **Control group**: Received usual OT for 60 min 2d/52 for 4 m for both hands. – **Tx group**: Received usual OT for the L hand for 40 min 2d/52 for 4 m + virtual reality therapy (LMC for fine motor and functional training with visual and auditory feedback) for the remaining 20 min for the R hand (60 min total). Played 3 LMC games: cube grasping (finger flexion), flower petal removal (pinching) and balloon or bird shooting (finger abduction and adduction)	– Statistically significant improvements in BSHS-B, QuickDASH, and iADL in the Tx group (all $p < 0.05$) compared to the control group at 4 m. – LMC-trained hand (Tx group R hand): AROM of the thumb IP joint and pinch and grip strength ↑ and scar thickness over the 1st dorsal interossei muscle ↓ ($p < 0.05$). – No significant improvement in scar thickness on the dorsal wrist and MCP joint of the index finger ($p > 0.05$) or for the control group.	Virtual reality VS Usual care 1) **Hand function** QuickDASH: 0.24 BSHS-B: 0.04 iADL: 1.15 Barthel index: 0.21 2) Not possible to calculate ES for other outcome measures since no SD was provided	3
Zeller et al. [49]	CS	n = 11 (7 hand burns) Age range= 25–55 y old TBSA range = 5.5–47%	Work Hardening Program – One intervention	1) RTW	The Work Hardening Program: 4–6 week program, 5 d/52 of physical reconditioning, job simulation, education, and evaluation and monitoring of work-related behaviors and attitudes. Hours of participation were graded weekly, with the 1st week requiring 4 hrs/d ↑ to 8 hrs/d the final week.	– No statistical analysis provided. – 91% RTW after discharge compared 60% for the total work hardening population at this facility.	N/A	4

ADL= Activities of Daily living; AROM = active range of motion; BSHS-A=Burn specific health scale abbreviated; BSHS-B= Burn specific health scale brief; BSHS= Burn specific health scale; CC=Case control; CO=cohort; CS=Case series; d = day; D=digit; DIP= distal interphalangeal joint; EROM = end range of motion; ES=effect size; FAB= Functional assessment for Burns; FIM= Functional independence measure; hrs = hour; IADL= Instrumental Activities of Daily Living; IP=inpatient; IQR= interquartile range; IRR= incident rate ratio; JHFT=Jebsen Hand Function Test; L=left; LOS= Length of stay; m = month; min = minutes; MBI= Modified Barthel Index; MCP= metacarpophalangeal joint; MHQ=Michigan Hand Outcomes Questionnaire; MPUT = Moberg Pick-Up Test; NRS =Non-randomized studies; OP=outpatient; OR= odds ratio; OT= Occupational therapy; PIP= proximal interphalangeal joint; POD=post-operative day; POSAS= Patient and Observer Scar Assessment score; PPT= Purdue Pegboard test; PROM = passive range of motion; PT=physiotherapy; QoL= Quality of life; R=right; RCT=randomized controlled trial; RT=resistance training; RTW = return to work; SCD/MPD=single case design or multiple case design; SF-36 = Medical Outcomes Study 36-Item Short Form; TBSA= Total body surface area burned; Tx=Treatment; UE=upper extremity; VAS= Visual analogue scale; VSS= Vancouver scar scale; x = times; y = years; /52 =per week.

consensus. A third assessor (BN) then verified the final data extraction form. The following data was extracted: participant sociodemographic details, intervention characteristics, outcome measures, main results, and adverse effects.

2.5. Methodological quality assessment

All studies were scored independently by two authors (ZEL & ED) using the critical review form for quantitative studies by Law et al. [19]. This form is comprised of fourteen items relative to study purpose, literature review, study sample, outcomes, interventions, results, conclusions, and clinical implications (Table 3). Each item was scored as yes [1] or no/ not applicable (0) and a total score was calculated for each article. When disagreements occurred, both authors discussed until consensus. When consensus was not achieved, a third blinded author (BN) served as a tiebreaker.

2.6. Data synthesis and analysis

The data was synthesized according to the main targeted outcomes measured. Due to the heterogeneity of the outcomes in the included studies, it was not possible to perform a meta-analysis. Furthermore, since 12 out of the 35 included studies did not have a control group or comparison group, it was not possible to calculate the effect size of each intervention. However, to compare treatment effect for studies with the same treatment that did have comparison groups, the effect size (ES) was calculated using Cohen's d when mean and standard deviation was reported. When the endpoint change (pre-post) scores for the intervention and the control group were available, the ES was calculated with these values. If not, the ES was calculated with the endpoint score. Treatment effects were then classified as small (< 0.20), moderate (0.50), large (0.80), and very large (> 1.30) according to Cohen's criteria [20,21].

3. Results

3.1. Description of studies

The PRISMA flowchart of this review is presented in Fig. 1. Thirty-five studies met the selection criteria and were included in this review. During the review process, 4 articles were removed, because 2 articles did not have enough details describing the intervention [22,23], 1 article had two studied groups, but only one who had burned hands [24] and 1 article did not use any of the outcome measures of interest [25] (Fig. 1).

3.2. Characteristics of included studies

Table 2 summarizes the study characteristics, sociodemographic data, outcome measures, intervention, results, and level of evidence for each of the 35 studies. Fourteen studies were RCTs [15, 26–38], 2 were a NRS [39,40], 4 were case-controls [14, 16, 41, 42], 7 were case-series [25, 43–49], 3 were cohort studies [50–52], 3 were single case design [53–55] and 2 were multiple case design. Sample size of the RCTs ranged from 6 to 100. The sample size for all the studies ranged from 1 to 100.

One study presented two case studies with one of the two aged < 18 y old [56]. Thus, the extracted data for this study was done solely for the adult participant. Two studies included participants younger and older than 18 years of age, but were included since the mean age for the participants was > 18 y old [33,47] even though the details of the adult participants could not be extracted. All other studies only included adult participants.

Articles were categorized according to the primary outcome targeted by the intervention: 1) hand function, 2) level of impairment/disability, 3) range of motion (ROM), 4) strength, 5) edema, 6) scar characteristics, 7) level of burn knowledge, and 8) return to work. Most studies targeted more than one outcome (51%; 18/35) [14, 15, 26–28, 30, 31, 34, 39, 40, 44, 45, 48, 51, 54–57]. Hand function was a targeted outcome in 43% (15/35) of studies, level of impairment/disability in 23% (8/35), ROM in 51% (18/35), strength in 34% (12/35), edema in 20% (7/35), scar characteristics in 9% (3/35), level of burn knowledge in 6% (2/35), and return to work in 3% (1/35). Other secondary outcomes were measured in 34% (12/35) of the studies [14–16, 26, 29, 38, 40–42, 47, 48, 51] and included measures such as: pain, graft loss, need for reconstructive surgery, functional sensation, quality of life (QoL), motor imagery vividness score, mental chronometry, patient satisfaction, patient rating of difficulty of performed tasks, duration of lunch (time) and weight of food spilled.

Studies were assigned a level of evidence according to the updated Oxford Center for Evidence-based Medicine Levels of Evidence [58]. Most of the included studies were Level 4 (46%; 16/35) and Level 2 (40%; 14/35) evidence. Only five studies were classified as Level 3 (14%; 5/35) evidence (Table 2) and none were considered Level 1.

3.3. Quality assessment of studies

Table 3 summarized the critique results for the 35 included studies. Most studies received a score of 5–9 (54%; 19/35) (Moderate quality). Fourteen studies received a score of ≥ 10 (40%; 14/35) (High quality) and only 2 studies received a score of < 5 (6%; 2/35) (Low quality).

3.4. Effects of interventions

3.4.1. Hand function

Fifteen studies investigated the effect of various interventions on hand function [15, 16, 26, 30, 31, 33, 34, 39, 40, 43, 48, 51, 52, 54, 55].

Three studies investigated the effects of compression on hand function. A RCT by Edwick et al. [26] reported that all compression methods studied (adhesive compressive wrap and compression glove) resulted in a significant increase in hand function compared to baseline. Lowell et al. [54] also reported an increase in hand function (decreased 9-hole peg test time) with the use of an adhesive compressive wrap. Park et al. [51] reported that compression bandages resulted in a small effect on hand function at 4 weeks (w) (ES=0.27), but no effect at 4 months (m) (ES=0.031).

Table 3 – Summary of critical appraisals.

YES = 1; NO = 0; N/A = 0

Citation	Study Purpose	Literature review	Design	Sample			Outcomes		Intervention			Results				Conclusion appropriate	Total
				Size	Details	Justified	Reliable	Valid	Described in Detail	Contamination	Cointervention	Statistical Significance	Analysis appropriate	Clinical Importance	Drop-outs Reported		
Aghajanzade et al. [43]	1	1	CS-prosp	30	1	0	1	1	0	0	0	1	0	1	0	1	8
Ause-Ellias et al. [44]	1	1	CS-prosp	5	1	0	1	1	1	0	0	1	1	1	0	1	10
Choi et al. [15]	1	1	RCT	42	1	0	1	1	0	0	0	1	0	1	0	1	8
Covey et al. [38]	1	0	RCT	10	1	0	1	0	1	0	0	0	0	1	0	1	6
Dewey et al. [14]	1	1	CC-retro	71	1	0	0	0	1	0	0	1	1	1	0	1	8
Dewey et al. [53]	1	1	SCD	1	1	0	0	0	1	0	0	0	0	1	0	1	6
Edgar et al. [45]	1	0	CS	14	1	0	1	1	1	0	0	1	1	1	0	1	9
Edwick et al. [26]	1	1	RCT	100	1	1	1	1	1	0	0	1	1	1	1	1	12
Elsherbiny et al. [27]	1	1	RCT	60	1	0	1	0	0	0	0	1	1	1	0	1	8
Ghalayini et al. [50]	1	1	CO	10	1	0	1	1	1	0	0	1	1	1	1	1	11
Gittings et al. [28]	1	1	RCT	48	1	1	1	1	1	0	0	1	1	1	1	1	12
Grisbrook, Reid et al. (2012)	1	1	CC	18	1	0	1	1	0	0	0	1	1	1	0	1	9
Guillot et al. [29]	1	1	RCT	14	0	0	0	0	1	0	0	1	1	1	0	1	7
Hwang et al. [46]	1	1	CS-prosp	24	1	0	1	1	1	0	0	1	1	1	0	1	10
Joo et al. [32]	1	1	RCT	57	1	1	1	1	1	0	0	1	1	1	1	1	12
Kamal et al. [31]	1	1	RCT	40	1	0	1	0	0	0	0	1	1	1	0	1	8
Li et al. [32]	1	1	RCT	60	1	0	1	1	1	0	0	1	1	1	0	1	10
Lowell et al. [54]	1	1	SCD	1	1	0	1	1	1	1	0	0	0	1	0	0	8
Mohaddes Ardebili et al. [33]	1	1	RCT	60	1	1	1	0	0	0	0	1	1	1	0	1	9
Nam et al. [57]	0	1	MCD	3	1	0	0	0	1	0	0	0	0	1	0	1	5
Neeman.[56]	0	1	MCD	2	1	0	1	1	1	0	0	0	0	1	0	1	7
O'Brien et al. [16]	1	1	CC	23	1	0	0	0	1	0	0	1	1	1	1	1	9
Omar et al. [34]	1	1	RCT	30	0	0	1	0	1	0	0	1	0	1	0	1	7
Paratz et al. [40]	1	1	NRS	30	1	1	1	1	1	0	0	1	1	1	1	1	12
Park et al. [51]	1	1	CO-retro	42	1	0	1	1	1	0	0	1	1	1	0	1	10
Pruksapong et al. [35]	1	1	RCT	12	1	0	1	1	1	0	0	1	1	1	1	1	11
Puri et al. [47]	1	1	CS-prosp	42	1	1	0	0	1	0	0	1	1	1	1	1	10
Pusineri et al. [55]	0	0	SCD	1	1	0	0	0	1	0	0	0	0	1	0	1	4
Riaz et al. [36]	1	1	RCT	80	1	0	1	1	1	0	0	1	1	1	0	1	10
Richard et al. [37]	1	0	RCT	6	1	0	0	0	1	0	0	1	0	1	0	0	5

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Table 3 – (continued)

YES = 1; NO = 0; N/A = 0				Sample			Outcomes		Intervention			Results					
Schneider et al. [52]	1	1	CO-prosp	11	1	0	1	1	1	0	0	1	1	1	1	1	11
Shi et al. [42]	0	1	CC	28	1	0	1	0	1	0	0	1	1	1	0	1	8
Weinstock-Zlotnick et al. [48]	1	1	CS	2	1	0	1	0	0	0	0	1	0	0	0	1	6
Wu et al. [39]	1	1	NRS	16	1	1	1	1	1	0	0	1	1	1	1	1	12
Zeller et al. [49]	0	0	CS	11	1	0	0	0	1	0	0	0	0	1	0	1	4

CC=Case control; CO=cohort; CS=Case series; NRS =Non-randomized studies; prosp=prospective; RCT=randomized controlled trial; retro=retrospective; SCD/MPD=single case design or multiple case design

Two studies investigated the effect of different types of hand compression garments on hand function. O'Brien et al. [16] reported that participants had significantly better hand function when wearing the New York Presbyterian Dexterity Glove compared to when wearing standard burn pressure gloves. Weinstock-Zlotnick et al. [48] also reported that participants wearing a specialized pressure garment glove (the pressure garment work glove) had significantly better gross and fine-motor movements compared to when wearing a standard-pressure garment glove.

Three studies investigated the effect of virtual reality (VR) on hand function. Joo et al. [30] reported that the use of the RAPAEL Smart Glove TM VR system resulted in significantly improved ability to pick up small objects and simulated feeding compared to standard therapy. There was also a small to medium effect on patient perceived hand function (ES=0.35). Pusineri et al. [55] also reported a gradual improvement in hand function with the use of virtual reality. Wu et al. [39] reported significant improvements in hand function using the Leap Motion controller VR system compared to usual rehabilitation. This intervention had a small to very large effect on hand function depending on the outcome measured (ES: QuickDASH=0.24; BSHS-B: 0.04, iADL: 1.15, Barthel index: 0.2).

Two studies investigated the effect of orthoses on hand function. Choi et al. [15] reported that the use of a dynamic metacarpal phalangeal (MCP) orthosis had a large to very large effect on hand function (ES=0.93). Kamal et al. [31] also reported that the use of a dynamic MCP orthosis had a very large effect on hand function (pre-post ES=6.41). The use of a static orthosis also had a very large effect on hand function (pre-post ES=1.6). However, the dynamic MCP orthosis had a very large effect post-treatment (ES=2.71) when compared to the static orthosis.

Two studies investigated the effect of general rehabilitation on hand function. Aghajanzade et al.[43] reported that participants had significant improvements in hand function after 8 weeks of occupational therapy. Schneider et al. [52] reported that hand function significantly increased during inpatient rehabilitation.

Two studies investigated the effect of specific rehabilitation on hand function. Mohaddes Ardebili et al. [33] reported that a patient education program resulted in significant improvements in hand function compared to the control group (usual care) after intervention. A RCT resulted in significant improvements in hand function compared to the control group (usual care) after intervention. A NRS by Paratz et al. [40] reported that participating in an intensive exercise program had a small to medium effect on hand function at 6w (ES=0.36) and a medium effect at 3 m (0.50).

Finally, Omar et al. [34] reported significant improvements in hand function after electric stimulation plus usual care compared to usual care.

3.4.2. *Level of impairment/disability*

Eight studies investigated the effects of various interventions on the level of impairment and/or disability [27, 28, 41, 42, 45, 50, 53, 57].

Three studies investigated the effect of general rehabilitation. Edgar et al. [45] reported an increase in patient

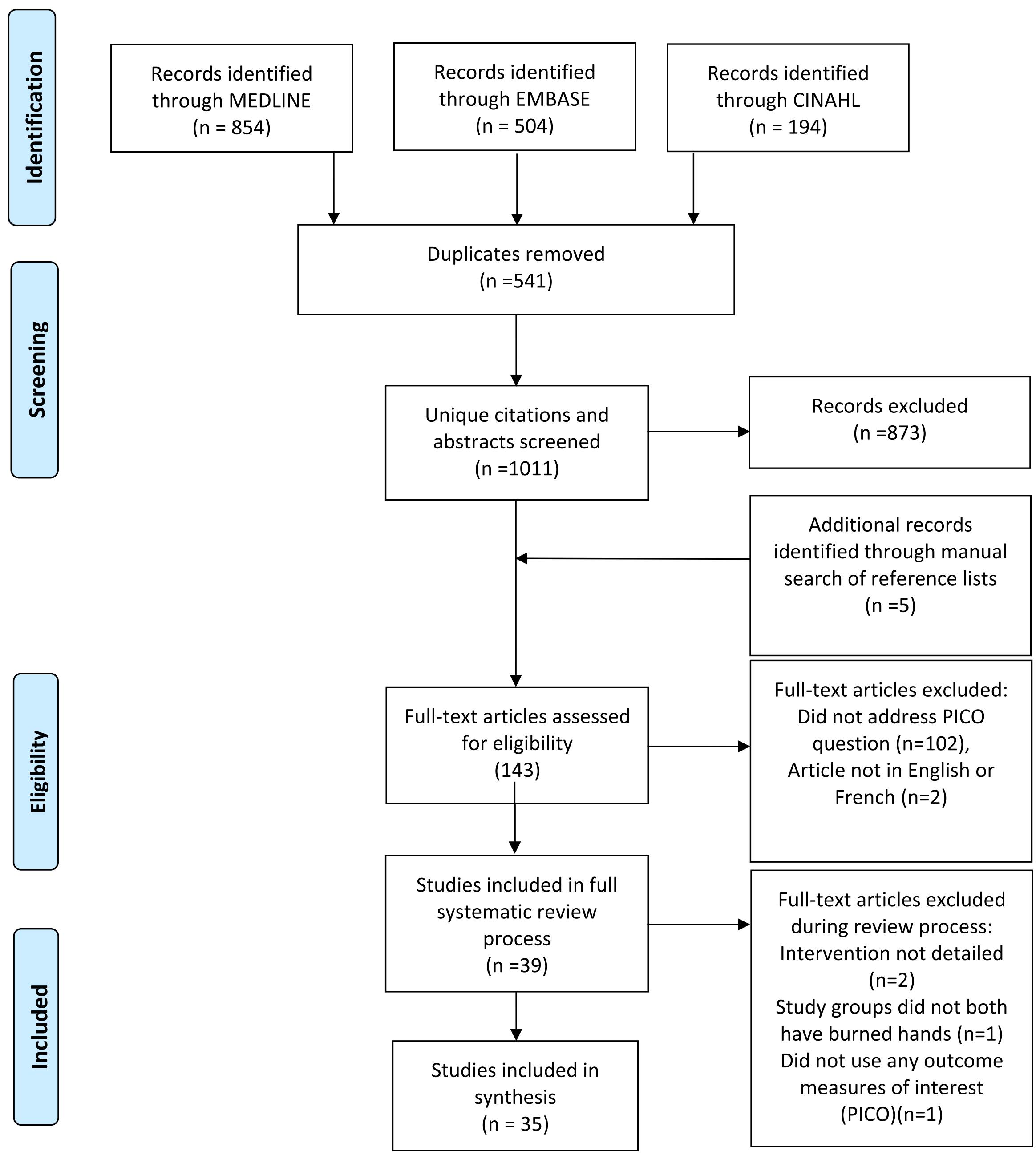

Fig. 1 – PRISMA flow diagram mapping out the number of records identified, screened, assessed for eligibility, and included in the full review process and synthesis.

perceived physical function after 3–6 m of regular OT/PT sessions. Elsherbin et al. [27] reported a significant improvement in patient perceived physical function after 1 m of rehabilitation with a burn education component. This intervention had a very large effect on patient perceived physical function at 1 m (ES=3.00) that was maintained 3 m post-treatment (ES=2.00). Ghalayini et al. [50] reported that OT sessions allowed acute inpatients to significantly improve their perceived level of disability during inpatient that continued to improve until 3 m post-discharge. However, the most substantial recovery occurred within the first 3 m post discharge.

Two studies investigated the effect of some type of exercise training. A RCT by Gittings et al. [28] reported that resistance training combined with standard physiotherapy resulted in a significant increase in patient perceived physical function and a significantly greater rate of improvement for patient perceived level of disability compared to standard physiotherapy only. However, a case-control study by Grisbrook et al. [41] reported that exercise training (interval training and resistance exercise) allowed for a non-significant improvement in patient perceived level disability after treatment with a small to medium effect (ES=0.27).

Two studies investigated the effect of adaptive equipment. In a single subject study by Dewey et al. [53] the use of a thumb opposition orthosis by an individual, who had a partial thumb amputation of the dominant hand, resulted in a significant decrease in the patient's upper extremity contribution to their total body impairment. Shi et al. [42] reported that the use of forearm pronation assist tableware, for individuals who were dependent for eating, significantly decreased their level of dependence compared to eating with an ADL universal cuff or without any assistive device.

Finally, a multiple case design study by Nam et al. [57] investigated the effect of a 3D printed orthosis. One participant demonstrated an increase in ADL performance and one participant demonstrated constant ADL performance after orthosis application.

3.4.3. *Range of motion*

ROM was the most commonly measured outcome with 18 studies that investigated the effects of various interventions to improve this outcome [14, 15, 26, 29, 31, 34, 36–39, 44, 46, 47, 51, 54–57].

Five studies investigated the effect of various compression interventions on ROM. Ause-Ellias et al. [44] reported that the use of an intermittent compression pump allowed for an average increase in PIP joint flexion of 3.37° and an average decrease in MCP joint flexion of 0.23°, but these results were not statistically significant. Edwick et al. [26] reported that there was a nonsignificant improvement in hand composite flexion and wrist extension between sessions of the application of an adhesive compressive wrap (ceiling effect) and a significant improvement in hand span and wrist flexion between sessions for the application of an adhesive compression wrap and for the use of a compression glove. Lowell et al. [54] reported that the use of an adhesive compressive wrap allowed for the participants to maintain postoperative gains compared to the use of a standard gauze dressing. Park et al. [51] demonstrated that the use of compression bandages had a small effect on PIP AROM (ES=0.24), but a very large effect on MCP AROM (ES=1.77). Richard et al. [37] reported that static wrapping resulted in a significant increase in MCP joint ROM and passive exercises resulted in a significant increase in PIP joint ROM.

Five studies investigated the effect of various orthoses on ROM. Choi et al. [15] reported that a dynamic MCP orthosis had a large to very large effect on MCP AROM (ES: right=1.10; left=1.37) and a small to medium effect on PIP AROM (ES: right=0.37; left=0.39). Kamal et al.[31] reported that MCP AROM significantly improved post-treatment for both the dynamic and the static orthosis groups. Nam et al. [57] reported ROM improvements in all 3 participants who wore 3D-printed finger splints. Neeman et al. [56] reported that an orthokinetic orthosis resulted in improvements in active flexion of 2nd, 3rd, 4th and 5th digits, but no improvement of thumb active flexion. These latter two studies did not provide any data analyses. Puri et al. [47] reported that a serial static orthosis resulted in a statistically significant improvement in ROM for the MCP, PIP and DIP joints and complete correction of contracture was achieved in 28.7% of thermal burns.

Two studies investigated the effect of VR on ROM. Pusineri et al. [55] reported that VR resulted in a gradual improvement in mobility and the patient recovered an almost complete fist after treatment. Wu et al. [39] reported that VR resulted in a significant improvement of AROM of the thumb IP joint and nonsignificant AROM improvement in the MCP joint of the index finger.

Hwang et al. [46] reported that the use of webspace pressure inserts significantly reduced the mean dorsal slant angle.

Dewey et al. [14] reported that patients who underwent early ROM (1–2d post-op) were more likely to achieve full-composite digital flexion by their initial outpatient follow-up appointment compared to patients who started ROM exercises at 3–5d post-op.

Guillot et al.[29] reported that motor imagery had a small effect on finger-to-thumb opposition (ES=0.21), a medium to large effect on finger flexion and wrist extension (ES= 0.77 and 0.78 respectively) but no effect on wrist flexion (ES=0.09).

Omar et al. [34] reported that the application of electric stimulation in addition to usual care had a very large effect on total AROM of fingers (ES=4.33).

Covey et al. [38] reported that the use of a continuous passive motion device (CPM) was comparable to conventional hand therapy in regaining total AROM.

Riaz et al. [36] reported that ultrasound therapy had a small to medium effect on PROM post-treatment (ES=0.36), paraffin wax therapy had a large effect on PROM post-treatment (0.80) and paraffin had a very large effect on PROM compared to ultrasound therapy (ES=1.38).

3.4.4. *Hand/grip strength*

Twelve studies investigated the effect of various interventions on strength [15, 28, 30, 31, 39, 40, 45, 48, 51, 54–56].

Three studies investigated the effect of VR on strength. A RCT by Joo et al. [30] reported that use of the RAPAEL Smart Glove TM system had a medium effect on grip strength (ES=0.53) and large effect on lateral and tip pinch strength (ES=0.89 and ES=0.83). A single case study by Pusineri et al. [55] reported that the patient increased their grip strength by 28.5 kg after treatment with VR combined with usual OT. Wu et al.[39] reported that the pinch and grip strength significantly improved pre-post treatment with the use of the VR system "Leap motion controller", but the post-treatment strength was not significantly different than the control group who received traditional OT.

Three studies investigated the effect of orthosis wear on strength. A RCT by Choi et al. [15] reported that the use of a dynamic MCP orthosis had a small effect on grip strength (ES: right hand= 0.16, left hand = 0.22). In contrast to this study, a RCT by Kamal et al. [31] reported that the use of both a modified dynamic MCP orthosis and a static orthosis had a very large effect on grip strength (ES=2.35 and 2.01 respectively). When comparing the dynamic to the static orthosis, the dynamic orthosis had a medium to large effect on grip strength (ES=0.66). Finally, a multiple case design study by Neeman et al. [56] reported that the use of an orthokinetic orthosis resulted in a substantial improvement in grip strength that was maintained 24 h later.

Three studies investigated the effect of compression on strength. Lowell et al. [54] reported that grip strength increased from postoperative day 17–31 (35–61 lbs) with the use of an adhesive compressive wrap. Park et al. [51] reported that compression bandages had a small effect on grip strength at 4 m (ES=0.25), but no effect at the end of the intervention at 4w (ES=0.11). Weinstock-Zlotnick et al. [48] reported that grip and pinch strength significantly decreased when using a pressure garment work glove compared to a standard-pressure garment glove.

Two studies investigated the effect of exercise training on strength. Gittings et al. [28] investigated the effect of resistance training on muscle strength, but the results were a combination of multiple muscle groups, therefore, results specific to hand strength could not be extracted. A NRS by Paratz et al. [40] reported that participating in an intensive exercise program had a small effect on grip strength after a 6w program (ES: right hand =0.22; left hand=0.22), but there was no effect at 3 m (ES: right hand=0.07; left hand=0.002).

Finally, a study by Edgar et al. [45] investigated the effect of general rehabilitation on strength. Male grip strength increased until 12 m after discharge, but the mean grip strength was below normative data at all time points. Grip strength means for women exceeded the 95%CI for population norms by 6 m and plateaued at that time.

3.4.5. *Edema*

Seven studies investigated the effects of various interventions on edema [14, 26, 28, 34, 44, 51, 54].

Four studies investigated the effect of compression on edema. Edwick et al. [26] reported that the application of an adhesive compressive wrap was significantly superior to the use of a compression glove for reducing hand edema. Lowell et al. [54] reported that the use of an adhesive compressive wrap was an effective way to reduce hand edema with a clinically significant difference compared to standard gauze dressing. Park et al. [51] reported that a modified compression bandage had a medium to large effect on edema reduction after 4w (ES=0.66) but almost no effect compared to not using the bandage at 4 m (ES=0.10). Ause-Ellias et al. [44] reported that the use of an intermittent compression pump reduces hand volume on average by 9.45 ml.

A study by Omar et al. [34] reported that electric stimulation had a very large effect on edema reduction (ES=1.71).

A study by Dewey et al. [14] reported that early ROM (1–2 days post-op) did not result in a significant difference in edema reduction compared to ROM after 3–5 days post-op.

Finally, a study by Gittings et al. [28] reported no difference in the change of edema over time between individuals who received standard physiotherapy plus resistance training program compared to those who only received standard physiotherapy.

3.4.6. *Scar characteristics*

Three studies investigated the effect of various interventions on scar characteristics [35, 39, 51].

Park et al. [51] reported that a modified compression bandage had a large effect on skin thickness reduction after 4w (ES=0.86) but almost no effect compared to not using the bandage at 4 m (ES=0.17).

Pruksapong et al. [35] reported that scar thickness significantly improved with the use of a silicone gel and pressure garment compared to the use of a pressure garment only. Scar irregularity showed significant improvement with silicone sheet and silicone gel (combined with pressure garment) compared to pressure garment alone.

Wu et al. [39] reported that the scar thickness over the 1st dorsal interossei muscle significantly decreased with OT treatment combined with VR compared to OT only.

3.4.7. *Level of burn knowledge*

Two studies investigated the effect of rehabilitation with an education component on the level of burn knowledge [27,32].

Li et al. [32] reported that the use of the rehabilitation intervention model, with an education component to guide rehabilitation interventions, had a very large effect on the patient's level of burn knowledge at discharge from the hospital (compared to usual care) (ES=1.36). Elsherbiny et al. [27] reported that participants who had an education component as part of their rehabilitation program had significantly higher burn knowledge than those who underwent usual rehabilitation. The education combined with usual rehabilitation showed a very large effect on burn knowledge at 1 m (ES=3.55) that was maintained at 3 m (ES=3.50).

3.4.8. *Return to work*

Zeller et al. [49] was the only study from this review that investigated the effect of a "Work hardening program" on return to work. This case series reported that participants who underwent the Work Hardening Program had a 91% return to work rate of burn survivors after discharge compared to the overall rate of return to work from this facility that underwent usual rehabilitation (60%).

3.4.9. *Other outcomes*

For studies that reported other secondary outcomes, pain and quality of life were the only two outcomes that were reported in more than one study from this review.

Three studies evaluated pain outcomes following rehabilitation [26, 38, 51]. A RCT by Covey et al. [38] reported that pain was minimal in both "conventional hand therapy" and "continuous passive motion" groups. In another RCT, Edwick et al. [26] reported a non-significant decrease in pain with the application of an adhesive compressive wrap to reduce edema. Contrary to this study, Park et al. [51] reported a very large effect of compression bandages for the reduction of pain at 4w and 4 m (ES: 4w=1.28; 4 m=1.94).

Three studies investigated the effect of a variety of interventions on quality of life [15, 40, 41]. A RCT by Choi et al. [15] reported that the use of a dynamic MCP orthosis had almost no effect on QoL (ES=0.09). Grisbrook et al. [41] reported that exercise training resulted in a non-significant improvement on total BSHS-B scores and a significant improvement on total SF-36 scores (both measures aimed to evaluate QoL in this study). A NRS by Paratz et al. [40] reported that participating in an intensive exercise program had a small effect on QoL at 6w and a medium effect at 3 m (ES: 6w=0.36; 3 m=0.56).

4. Discussion

4.1. *Summary of main results and quality of the evidence*

This review was undertaken to investigate the effects of rehabilitation interventions in achieving optimal outcomes following hand burns. We assessed changes in hand function, range of motion, strength, edema, scar characteristics, return to work, level of impairment/disability and level of burn knowledge.

It is to be noted that some outcome measures were used to evaluate different constructs depending on how studies used them. For example, Aghajanzade et al. [43] used the DASH to evaluate hand function, but this same measure was used by Dewey et al. [53], to measure patient perceived disability. Therefore, we presented the results according to how each study interpreted the results of each outcome measure.

Due to the heterogeneity of the study designs and interventions, it is difficult to make strong conclusions on the effectiveness of the presented treatments. However, it is possible to make clinically relevant statements concerning interventions that were reported in more than one study, had a large or very large effect size, when more rigorous methodological approaches were used and when the quality of the research report was higher (Table 3). Therefore, the clinical use of interventions was suggested when reported in either: one high quality RCT or two moderate quality RCTs or two high quality NRS/CO/CC/CS or one high quality NRS/CO/CC/CS and one moderate quality NRS/CO/CC/CS.

The following interventions reported an increase in hand function in more than one study: use of a compressive adhesive wrap, use of a specialized pressure garment glove, virtual reality, dynamic MCP orthosis and general rehabilitation.

- The use of an adhesive compression wrap in individuals with higher hand volumes was effective in increasing hand function in one high quality RCT and one moderate quality SCD [26,54]. Therefore, the use of an adhesive compression wrap is suggested in patients who have increased edema to increase hand function.
- The use of specialized pressure garments gloves demonstrated significantly better hand function compared to the use of standard-pressure garment gloves in one moderate quality CC and one low quality CS study [16,48]. Therefore, the use of a specialized pressure gloves could be used if available to increase hand function, but more studies are needed to evaluate the benefits of using specialized pressure gloves.
- The use of VR demonstrated significant improvement in hand function compared to usual rehabilitation in one high quality RCT and one high quality NRS [30,39]. One low quality SCD also reported a gradual improvement in hand function with the use of VR [55]. However, all three articles used different types of VR and “usual rehabilitation” was not described in detail. Nonetheless, we suggest the use of VR based rehabilitation to increase hand function when this technology is available in the clinical setting.
- Two moderate quality RCTs reported that the use of dynamic MCP orthosis had a very large effect on hand function [15,31]. Therefore, in the presence of hand contractures, the use of dynamic MCP orthosis is suggested to increase hand function.
- General rehabilitation showed significant improvement in hand function in one high quality CO study and one moderate quality CS study [43,52]. This finding further supports the statement from the “Guidelines for the operation of burn centres” that hand burns should always be referred to a specialized burn centre, which, by definition includes occupational and physical therapy treatments [6].

Other positive effects of interventions on hand function were only supported by one study single studies.

- The use of a patient education program significantly improved hand function in one moderate quality RCT [33]. More studies are required to determine if this effect is significantly better than usual rehabilitation. However, it is possible that many burn centers include a patient education component as part of their usual rehabilitation, since this is best practice when using a client-centered approach.
- Participating in an intensive exercise program had a small to medium effect on hand function in one high quality NRS [40]. Therefore, more studies are required to determine if this effect is significantly better than usual rehabilitation.
- The use of compression bandages demonstrated a small effect on increasing hand function in one CO study with high quality methodology [51]. Therefore, the use of an adhesive compression wrap in patients who have increased edema would be more effective to increase hand function compared to the available evidence on compression bandages.
- The use of electric stimulation combined with usual care showed significant improvements in hand function in one moderate quality RCT [34]. Therefore, more studies are needed to evaluate the efficacy of this treatment.

No interventions reported negative effects on hand function.

The following interventions reported a decrease in the level of impairment/disability in more than one study: general rehabilitation, exercise training and the use of adaptive equipment.

- Participating in general rehabilitation showed significant improvement in patient perceived level of disability in one moderate quality CS, one moderate quality RCT and one high quality CO [27, 45, 50]. Therefore, as mentioned for hand function, this supports the fact that hand burns should always be referred to a specialized burn centre.
- One high quality RCT and one moderate quality CC study reported that exercise training such as resistance training improved patient perceived level of functional impairment [28,41]. However, this increase was not significant in both articles. Thus, there is a lack of evidence that

exercise training is more effective than usual care in increasing patient perceived level of functional impairment following hand burns.
- One moderate quality CC study and one low quality SCD reported that the use of adaptive equipment decreased patient level of dependence [42,53]. However, the adaptive equipment used were different in both articles and prescribed according to the patient's needs. Therefore, the use of adaptive equipment is suggested based on patient's needs and specific limitations following burn injury to decrease their level of dependence, but higher quality studies are needed to determine their effect.

Only one low quality MCD study reported that the use of 3D printed orthosis either increased or maintained ADL performance [57]. Therefore, there is insufficient evidence to support the use of 3D printed orthosis to increase ADL performance following hand burns.

No interventions reported negative effects on the level of impairment/disability.

The following interventions reported an increase on ROM in more than one study: compression wrapping/bandages, orthoses, and virtual reality.

- One high quality RCT, one moderate quality RCT, one moderate quality SCD and one low quality CO study reported that the use of compression wrapping/bandages increased ROM in patients with high hand volumes [26, 37, 51, 54]. Thus, there is sufficient evidence to suggest their use.
- Two moderate quality RCTs, two moderate quality MCD studies and one high quality CS all reported that the use of orthosis (different types) increased ROM [15, 31, 47, 56, 57]. Therefore, the use of an orthosis is suggested to increase ROM following hand burns.
- One high quality NRS and one low quality SCD reported that the use of VR increased ROM [39,55]. However, both studies did not use the same type of VR and there is little evidence that VR is superior to usual care in increasing ROM.

Other positive effects of interventions on ROM were only supported by one study single studies.

- One high quality CS reported that the use of webspace pressure inserts significantly reduces the mean dorsal slant angle [46]. However, further studies are required to determine if this intervention provides a larger effect on ROM compared to other clinically used interventions such as gels or other types of inserts.
- One moderate quality CC study revealed that early ROM post-op grafting was more likely to achieve full-composite digital flexion following hospital discharge [14]. However, more studies are needed to evaluate the efficacy of this treatment.
- One moderate quality RCT reported that motor imagery had some effect on wrist and finger ROM [29]. However, more studies are needed to evaluate the efficacy of this treatment for hand burns.
- One moderate quality RCT reported that the application of electric stimulation in addition to usual care had a very large effect on ROM [34]. However, more studies are needed to evaluate the efficacy of this treatment.
- One high quality RCT reported that paraffin wax therapy had a large effect on PROM [36]. Therefore, the use of paraffin is suggested to increase hand PROM following burn injury once no open wound is present.

One high quality CS reported that the use of an intermittent compression pump decreased MCP joint flexion by 0.23°, thus it is possible that this intervention has negative effects on MCP ROM [44].

Virtual reality and the use of orthosis measured strength as an outcome in more than one study.

- One high quality RCT, one high quality NRS and one low quality SCD reported that the use of VR significantly increased hand strength [30, 39, 55]. However, all three articles used different types of VR and "usual rehabilitation" was not described in detail. Nonetheless, we can recommend the use of VR based rehabilitation to increase hand strength when this technology is available in the clinical setting.
- The three studies that investigated the effect of orthosis on hand strength presented conflicting results. A moderate quality RCT by Choi et al. reported that the use of a dynamic MCP orthosis had a small effect on hand strength while another moderate quality RCT by Kamal et al. reported it had a very large effect [15,31]. Furthermore, a moderate quality MCD study by Neeman et al. reported the use of an orthokinetic orthosis resulted in substantial improvement in grip strength. Thus, these conflictual results do not allow us to conclude any recommendations on the use of orthosis to increase hand strength.
Other positive effects of interventions on strength were only supported by single studies.
- A high quality NRS reported that an intensive exercise program had a small effect on hand strength [40]. Further investigations are needed to determine if different types of exercise programs could have different effects on hand strength.
- A moderate quality CS reported that general rehabilitation increased hand strength [45], but further investigations are needed to determine the size of its effect.

Compression reported a decrease in edema in more than one study.

- All studies who used compression (one high quality RCT, one high quality CO study, one high quality CS study and one moderate quality SCD) reported a decrease in edema [26, 44, 51, 54]. Therefore, we can strongly suggest the use of compression (adhesive compressive wrap, compression bandage and intermittent compression pump) to decrease hand edema following burn injury. However, further investigations are needed to determine what types of compressions are superior.

Other effects of interventions on edema were only reported in single studies.

- A moderate quality RCT reported that electric stimulation had a very large effect on edema reduction. However, more studies are needed to evaluate the efficacy of this treatment [34].
- A moderate quality CC study reported that early ROM (1–2 days post-op) did not result in a significant difference in edema post graft surgery compared to usual ROM protocol (3–5 days post-op) [14].
- A high quality RCT reported that the participation in a resistance training program combined to usual physiotherapy was not superior in reducing edema compared to usual physiotherapy alone [28].

Positive effects of interventions on scar characteristics were only reported by single studies.

- A high-quality CO study reported that compression bandage had a large effect on skin thickness reduction after 4w, but almost no effect at 4 m [51]. Therefore, it is possible that the use of a compression bandage is effective to reduce scar thickness in the first month post-burn, but not superior compared to no bandage in the long-term effect. However, further studies are needed to establish the effect of this intervention and other types of compression on hand scar characteristics should be investigated (ex: compression garment gloves).
- One high quality RCT reported that the use of silicone gel with pressure garment significantly improved scar thickness compares to pressure garment alone. This high-quality study supports the use of silicone gel to reduce hand scar thickness following burn injury [35].
- One high quality NRS reported that scar thickness over the 1st dorsal interossei muscle significantly decreased with OT treatment combined with VR compared to OT only. Therefore, further studies are needed to investigate the effect of VR on scar thickness [39].

Rehabilitation with an education component had a positive effect on the level of burn knowledge in the two studies.

- One high quality RCT and one moderate quality RCT reported that an education component to rehabilitation had a positive effect on the level of burn knowledge. Therefore, the use of an education component is suggested to increase the level of burn knowledge following hand burns [27,32].

Finally, one low quality CS reported that the use of a work-specific rehabilitation program had a higher RTW rate at discharge compared to other burn survivors that did not undergo this program. However, higher-level evidence and quality studies are needed to determine the effect of this intervention [49].

4.2. *Strengths & limitations*

One of the strengths of this review is that it is the first knowledge synthesis that gathered all of the available literature on rehabilitation interventions for the treatment of hand burns in adults that provided a systematic critique of the quality of the included studies. Even though no practice guideline was able to come out of this review, clinical recommendations for the use of certain interventions were reported with the available evidence. We believe this paper will be a useful tool for burn rehabilitation clinicians who will have systematically evaluated data to support their professional reasoning and their treatment decisions targeting various hand outcomes.

Another strength is the calculation of the effect size for 12 of the studies, which will provide clinicians with additional objective data of the magnitude of the effect of different treatment interventions. Furthermore, this systematic review identified specific knowledge gaps that hopefully researchers will investigate in future projects (see Section 4.3).

On the other hand, this review has certain limitations. Firstly, all included articles were restricted to adults only, thus, treatments investigated with the pediatric population were not included. Furthermore, the design and interventions described in the included studies were quite heterogeneous making strong conclusions about the effectiveness of the treatments difficult. Finally, no bias evaluation could be performed.

4.3. *Future research recommendations*

The results of this review support the need for appropriately powered RCTs with rigorous methodology, well-defined interventions (using the TIDieR checklist) [59], and the use of appropriate statistical analyses when investigating hand burn rehabilitation interventions. This would also allow for future knowledge synthesis studies to investigate the effectiveness of specific interventions for the treatment of hand burns rather than investigate all interventions as we did in this review. However, many high-quality studies on the same interventions will be needed to conduct such a review. Furthermore, studies should include means, standard deviations for each outcome and the number of participants in each group to allow future reviews to calculate effect sizes, which are extremely valuable in the clinical setting.

This review also supports the need to investigate the effectiveness of other commonly used interventions for hand burns such as serial casting, orthoses, thermal modalities, functional dexterity programs, passive mobilization, sensory re-education programs, inserts, etc. Furthermore, many studies used patient reported measures to evaluate hand function, potentially due to the lack of performance outcome measures for hand function validated for the burn population, which is quite subjective. Thus, there is a need to develop or validate already existing hand function performance outcome measures for the burn population to objectively quantify hand function. Furthermore, pain should be more commonly evaluated when investigating hand burn treatment interventions due to the common occurrence of pain in hand rehabilitation [60]. Finally, since sensory feedback plays an important role in hand function and sensory impairments are common following burn injuries [61,62], studies investigating sensory reintegration interventions should be investigated following hand burns.

5. Conclusions

This systematic review synthesized and critiqued the existing literature that concerns rehabilitation treatments for hand burns. Furthermore, this review supports the clinical practice of the following interventions:

- The use of an adhesive compression wraps for patients who have increased edema to increase hand function and ROM.
- The use of compression (adhesive compressive wrap, compression bandage or intermittent compression pump) to decrease hand edema following burn injury.
- Participating in general rehabilitation to increase hand function and patient perceived level of disability.
- The use of an orthosis to increase ROM and a dynamic MCP orthosis to increase hand function.
- If available, incorporate the use of VR based rehabilitation to increase hand function and hand strength.
- The use of paraffin to increase hand PROM.
- The use of silicone gel to reduce hand scar thickness.
- The use of an education component in rehabilitation to increase the level of burn knowledge.

Further studies are needed to increase the body of high-quality literature concerning hand burn rehabilitation interventions.

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CRediT authorship contribution statement

Zoë Edger-Lacoursière: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing. **Erika Deziel:** Data curation, Validation, Writing – review & editing. **Bernadette Nedelec:** Data curation, Validation, Writing – review & editing, Supervision.

Conflicts of interests

The authors do not have any conflicts of interest to disclose.

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