Effectiveness of Fitting Pressure Garments for Minor and Moderate Burn Patients: A Literature Review

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ABSTRACT

Aim: Burn reconstruction and rehabilitation are difficult and time-consuming processes; a burn patient must endure a long rehabilitation process to treat burn scars. The continued proliferation of scars and anxiety engender considerable difficulties for patients. A burn scar contracture is like a burned rubber band; the skin is never restored to its original flexibility.

Wearing pressure garments (PGs) is uncomfortable and challenging for patients, but constant adherence is necessary. To improve adherence, precise knowledge about the advantages and disadvantages of PG therapy (PGT) is necessary.

Methods: This review examined experimental studies that have applied PGT on patients with varicose veins and burns, as well as healthy human controls. The participants answered questionnaires to determine the best or “ideal” pressure. All scars were treated under a scar management program and followed up by the treating hospital and scanned by ultrasound. Scars were assessed using the Tissue Ultrasound Palpation System (TUPS), as well as the Vancouver Scar Scale (VSS) for rating scar thickness, pliability, pigmentation, and vascularity. Scar thickness and color were objectively measured using the Pliance X system and Laser Doppler Imaging (LDI).

Results: In general, the application of 15–25 mmHg pressure is most commonly used in clinical practice. Minor and moderate burn patients could wear PGs in the very beginning of the recovery process. According to guidelines, closed scars should always be reevaluated 6 months after the burn to determine whether additional scar management interventions are required or whether preventive therapy can be terminated.

CCS Concepts

• Theory of computation

Keywords

Occupational therapists; hypertrophic scar; keloid; total body surface area (TBSA); rehabilitation; pressure garments (PGs); Vancouver Scar Scale (VSS).

1. INTRODUCTION

In the event of skin injury, the process of wound healing starts

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with a vascular response followed by an inflammatory response and subsequently proliferation and maturation [1–9]. Skin scar coloration is determined by the vascularity and pigmentation of the tissue involved. After cutaneous injury, abnormal skin coloration is a common complaint of scar sufferers [1, 5, 7, 10, 11].

All deep second- and third-degree burns are at risk of developing hypertrophic scars that can have a severe negative effect on a patient’s quality of life [2, 4, 11–22]. If these processes of wound healing are prolonged, they might lead to the development of hypertrophic scars [1–10, 23–26]. The remodeling process of collagen synthesis and lysis can last up to 2 years after tissue injury [2, 5, 7, 9, 10, 25].

Hypertrophic scarring is caused by the excessive deposition of collagen, resulting in an exaggerated wound healing response with a progressive increase in collagen synthesis [1–3, 5, 6, 8, 9, 24–26].

The nature of scarring appears to depend on factors such as the race, age, genetic predisposition, hormone levels, atopy, and immunologic responses of the patient, as well as the type of injury, wound size and depth, anatomic region affected, and mechanical tension on the wound [3, 4, 14, 19, 27].

Pressure garments (PGs) have been the mainstay of hypertrophic scar and keloid treatment since the early 1970s, probably due to their noninvasive characteristic and desirable treatment effects with few complications [10, 13, 22, 28–36]. PGs seem to reduce scar formation, improve scar appearance, and decrease pruritus, pain, and contractures. Although their efficacy has never been scientifically proven, PGs are widely used [7, 13, 30–34].

Traditionally, treatment of hypertrophic burn scars has involved several options for PG therapy that involve wearing garments made from elasticized fabrics. Mechanical loading by applying pressures of between 6 and 50 mmHg is routinely used to treat, control, or prevent several medical and pathologic conditions [22, 29, 31]. Silicone sheets and gels are recommended as the “gold standard” noninvasive therapies for both the prevention and treatment of hypertrophic scars and keloids, with gels being preferred by patients [2, 6, 8, 37].

Without the constant pressure of the garment, the collagen fibers of the scar tissue grow unsystematically. By contrast, the inner structure of a scar matures under constant pressure and more resembles the natural patterns of fibers found in healthy skin [7, 9, 24, 26, 38].

Most studies have applied a standard “reduction factor” of 10, 15, or 20 to determine the circumferential pattern of a PG according to a patient’s circumferential measurements [22, 29, 32, 33, 36, 39]. Many authors have reported that a PG of 25 mmHg was effective for burn patients [30–34], whereas other authors have recommended PGs of 15 mmHg [10, 36, 39]. In Taiwan, PGs

made domestically are likely to consistently exert the same amount of pressure as those manufactured in the United Kingdom.

This review examined experimental studies that have applied PGT on burn patients. The literature cited in this article includes the most relevant publications that were used to develop recent evidence-based guidelines.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1. Pressure garments

Machines and volunteers wore PGs during the tests [30–32, 35, 39, 40], which were based on a structured interview guideline [39, 41] or not elaborated upon by the authors [30–32, 35, 40] (Table 1).

2.1.2. Pressure therapy was started 2 to 3 weeks after healing [36, 42] (Table 2).

2.1.3. All participants were recruited and prescribed with two sets of garments for daily changing and instructed to wear the PGs 23 hours per day and remove them only before bathing [10, 36, 42, 43] (Table 2).

2.2 Methods

2.2.1. The reviewed studies were experimental in nature and included patients with burns or varicose veins, as well as healthy participants. Questionnaires were used to determine the best or “ideal” pressure [30–32], with the evaluated pressures ranging from 0 to 60 mmHg. This pressure range is comparable to the recommended pressure range commonly applied in clinical practice [34, 39] (Table 1).

2.2.2. Two different types of garments were used in this study. Each participant was given PGs for use on the individual scar regions, with a standardized mechanical pressure ranging from approximately 10 to 25 mmHg [10, 24, 36, 42]. All scars treated under a scar management program and followed up by the treating hospital were scanned by ultrasound [42, 44] (Table 2). These scars were assessed using the Tissue Ultrasound Palpation System (TUPS), as well as the Vancouver Scar Scale (VSS) for rating scar thickness, pliability, pigmentation, and vascularity [24]. Scar thickness and coloration were objectively measured using the Pliance X system [24] and Laser Doppler Imaging (LDI) [42, 45] (Table 2).

Table 1. Literature review of checklist for pressure and reduction

Authors	Year	Method	Pressure	Material	Machine	TBSA	Result	Remark
Lisa Macintyre.,et al.,	2005	1.Questionnaire. 2.test	0-60mmHg	PG	None	None	25mmHg	Reduction:20%
Lisa Macintyre.,et al.,	2007	To set different 2 group	Machine:0-40mmHg Reduction factor:10-50%	PG	I-SCAN9801 cylinder model	None	25mmHg	Limb 21 Healthy human Volunteers Accuracy of 2.5mmHg
S.Rippers.,et al.,	2009	Questionnaire.	no	PG	None	AVG:19.8% 21 Human	Psycho-education and special training	
Li-Tsang et al.,	2009	Phase 1: Laboratory tests Linearity and repeatability test. Phase 2: discriminant validity by clinical pressure measurement on hypertrophic scar tissues	10 mmHg – 50mm	PG	Pliance X system	None Aged(18 – 40) In totals,(24 HS with 3 – 8 months).	(under 10 mmHg). sensor placed between human limbs and a sphygmomanometer cuff with a maximum mean difference of 6.42%.	Focus on Limb 1.Five healthy volunteers 2.Eight objects(5 males&3femals)
Lisa Macintyre.,et al.,	2011	2-point power law and linear 0.75kg - 6.0754kg	0 – 44 mmHg	PG	I-scan	None	Accuracy of 2.1mmHg. 25mmHg	circumference $\geq$ 30cm
Beibei Feng et al.,	2013	SPMS Questionnaire	15mmHg	PG	SPMS	None	SPMS better than CG(15mmHg)	Varicose veins(26),M=56 years (mild to moderate)

3. RESULTS

The methods used in the reviewed studies were evaluated by measuring both the pressure delivered by the constructed PGs and the reduction of the scar thickness (Tables 1 and 2). These two methods (reduction and pressure) are the most commonly used pressure factors in the literature [30–33, 39]. Attention was also paid to limb circumference and PG measurements [30, 32, 35, 39, 40] (Table 1).

According to the construction technique described, a 20% reduction factor was achieved for a limb circumference of 20 cm at a pressure of 25 mmHg, which was considerably lower than the most commonly accepted “ideal” or optimal solution [28, 30–33] (Table 1). The pattern of change of the parameters correlated at a

high level of significance after 3 months of treatment [10, 36] (Table 2).

These data suggest that PGs that deliver a pressure of at least 15 mmHg tend to accelerate scar maturation after 3 months [10, 36, 40] (Table 1 and 2). Measurement for scars and thicknesses were taken each time by the same assessor (Minolta Chromameter CR-300) and repeated after 1, 2, and 3 months [36] of therapy. Burn scars were also evaluated by ultrasound scanning and LDI to determine severity. Participants in the studies were of Caucasian [36] and Chinese descent [10]. In most cases, substantial reduction in scar redness was only observed after 3 months of pressure intervention [10, 36]. An exception to this pattern was noted by Cheng and colleagues, who found that scar thickness reached a plateau 1.5 years after the injury and then began to

decline gradually [44] (Table 2). The mean peak thickness of these scars was high, and scars were slightly thicker at 6 months

than at 3 and 9 months postburn [42] (Table 2).

Table 2. Literature review of checklist for tools and methods

Authors	Year	Method	Pressure	Material	TBSA	Result	Machine	Patient's year	Remark
By W.Chang et.al.	2001	VGH(Vancouver General Hospital Burn Assessment Scale)	5-10 mmHg	PG	8.8%(1-21%) Trunk :limb=57%:48% 2 degree burn	1.5 year gradually	Ultrasound	Mean:2.8 years(0.5-15.8)years	Asian pediatric burn patient. M.F=36:22
Eric Vanden ,et al.,	2005	CR-300(1,2,3 months)	2 different types (10 & 15 mmHg)	PG	8%(1-30%) 76 burn scars	15 mmHg	CR-300	Avg.=37.5 Years (19 to 56 years) 60 patient.Female:44 Male:16	After 3 months. Caucasian Forearm, calf
E.R.La Hei	2006	Laser Doppler imaging(LDI) 6 Months 50scars	Not clear	PG	8%(1-34%) Two-thirds	LDI can predicting burn wound	LDI	The median range age was 5 to 15 years 18 boys, 13 girls	31 pediatric burn patients One patient not grafted
Xue-Qing Wang ,et al.,	2010	Laser Doppler imaging(LDI)(3,6,9 months)	15-25mmHg and silicone	PG	33 scars(LDI) A total of 60 Ultra. Shoulder,chest, back,arm ,leg,abdominal,anterior or neck	15-25mmHg After 6 months(scars higher than 3 & 9)	LDI& ultrasound	Mean.=5.88 Years (0-15years)	21 pediatric burn patient. Healing time=14-21 days(Avg.=20.5
Lai Hoi Yan Candy ,et. al.	2010	Two different pressures(after two months for a five month intervention) Pliance X & TUPS	2 different types (10-15mmHg & 20-25mmHg)	PG	-----	At least 20 mmHg	Pliance X & TUPS	These scars had been developed for three to nine months (L:28.24 H:24.43)years	17 Chinese(53 HS's sample Vancouver Scar Scale (VSS)
Cecilia W.P. Li-Tsang ,et.al.,	2015	Pressure garments (1 month and 3 month)	15 mmHg 2 different types (1 type wear PG, the other are none)	PG	6 burn patients: second degree burn patient	15mmHg	-----	Avg.=27.5 Years (16-44 Years)	Chinese people

The sensitivity of the sensors used in these studies can be adjusted using I-scan software to optimize the sensor output to a particular measurement range [30, 31]. Pliance X appears to be an effective device for measuring the interface pressure generated by PGs on skin tissue [24, 39]. Scanning probe microscopy also had the advantage of providing a standardized procedure for generating the pattern for garment fabrication using a computerized program (Tables 1-2).

When the VSS was used with PG therapy, the clinical estimation of scar thickness correlated well with ultrasound measurements. The accuracy rate of clinical thickness estimation was 67% [44]. Both LDI and the CR-300 are helpful tools to assist in the assessment of burn depth, which has been correlated with healing time [42, 46] (Table 2).

Some of the reviewed studies examined pediatric burn patients aged 0-15 years (mean: 2.8-5.88 years) and having 1%-33% (Mean: 8.5%-8.8%) total body surface area (TBSA) burns. These pediatric studies included 21 Australian and 58 Asian burn patients [42, 44]. Some of the studies included adult burn patient aged 19 to 56 years with 1%-30% (mean: 8%) TBSA burns among 60 Caucasian patients [36]. Vascularity decreased with the maturation of the scar from an average of 1.5 immediately after injury to 0.5 after 7 years for Asian pediatric patients [44]. Candy and colleagues showed that a static pressure of at least 20 mmHg accelerated scar remodeling with generally better clinical presentations compared with lower pressure levels on scars with severe hypertrophy [24] (Table 2).

Ultrasound is the most accurate and reproducible method available for measuring overall thickness above and below the skin surface, while the protruding part can be measured with a ruler. TUPS (Tissue Ultrasound Palpation System) is an

ultrasound measurement system validated for post-surgical hypertrophic scar assessment [25, 42, 44] (Table 2).

Many authors stated that 15 mmHg [10, 36, 40] is necessary to accelerate the maturation process and that effects of pressure below 10 mmHg pressure are minimal [39], so the ranged from 15mmHg to 25mmHg is good pressure for pressure garments[7, 10, 15, 22, 24, 30-36, 40, 42, 43, 45, 47]. Unfortunately the methodology of their study was not explained. With pressures above 40mmHg maceration a paresthesia may occur [10, 22, 28, 39].

4. DISCUSSION

All scars were under the standard scar management program with pressure garments of pressure between 15 and 25mmHg [7, 10, 15, 22, 24, 30-36, 40, 42, 43, 45, 47]. Those papers didn't talk very clear the location of burn, except these papers [42, 44]. It revealed that the mean of peak thickness of these scars was slightly thicker at 3 months [10, 42, 45].

An inhalation injury significantly increases the risk of mortality unless the burn is very small (<10% of TBSA)[48, 49]. Age is also an important predictor of survival. Contractures can be caused by immobility and heterotopic ossification at elbow joints [3, 12, 20, 41, 48, 50-52], but are frequently caused by hypertrophic scarring [2, 3, 6, 9, 11, 38, 53].

The basic principle is the application of constant pressure on the scars which is supposed to occlude the capillaries and restrict the availability of oxygen in the affected region. It is assumed that the lack of oxygen accelerates the maturation of the scar.[54] Based on various age, gender, race and scar management regimen [2]. Vancouver Burn Scar Assessment scored didn't correspond well to scar thickness and therefore would never be able to prove this co-evolution between erythema and thickness adequately[44].

A scar assessment scale, which subjectively evaluates the effectiveness of scar therapies, is an important evaluation tool because it describes the impression of experts on the appearance of scars. A scar assessment scale is considered suitable for the comparison of clinical results when it is tested as reliable, feasible, consistent, and valid. However, currently, no scar assessment scale is available that has proven to meet all of the aforementioned statistical requirements [15, 36, 55]. No overall valid and reliable noninvasive and objective assessment tool is available for measuring cutaneous scar characteristics [15, 56, 57].

Asians are more likely to develop hypertrophic scars compared with Caucasians, and Africans are more likely to develop hypertrophic scars than Asians [44, 58]. Hypertrophic scarring is very common among the Chinese population [24]. In general, hypertrophic scarring occurs more frequently in women and patients of younger age groups [13]. PGs are often uncomfortable and challenging for burn patients, leading to low adherence rates. To improve adherence, precise knowledge about the advantages and disadvantages of PG therapy is necessary [35, 40, 59].

5. CONCLUSION

The skin surface expands and contracts during body movement. Each point has a different maximum pull, especially at the hands, upper arms, elbows, and forearm, and impact on the parts of the body where tension is particularly severe [60, 61]. Many studies on the measurement of the human body were concerned with static measurement [7, 10, 30–35, 39]. Although some studies have simulated pressure sleeves and tubular trunk PGs [30, 31, 33, 34], the noncircular shape and special contours of the hands and limbs increase the difficulty of measuring or predicting the pressure given by a pressure therapy glove. Consequently, these limitations increase the difficulty in controlling and obtaining the optimum pressure over hypertrophic scars on the hand.

Most of the authors reviewed showed that pressure or compression therapy could promote hypertrophic scar maturation, restrain scar formation, improve appearance, minimize pruritus, and mitigate pain [1, 2, 4, 6, 7, 10]. Massage therapy could have a positive effect on scar pliability and pruritus, but less evidence exists in support of this modality [6]. However, other researchers have indicated that pressure therapy not only maintained the ultimate outcome of burn wounds unchanged but also increased the incidence of overheating, pain, blistering, wound breakdown, and abnormal bone growth [32, 62]. If patients must undergo treatment, then pressure therapy is an ideal option for hypertrophic scar and keloid treatment.

The putative advantages of pressure treatment include its ability

- a. to occlude capillaries, resulting in a lack of oxygen, which accelerates the maturation of the scar [54];
- b. to hasten the maturation process [34];
- c. to reduce scar thickness;
- d. to increase scar elasticity;
- e. to reduce scar bleeding;
- f. to reduce edema [36];
- g. to make collagen and rearrange epidermal tissue [36];
- h. to reduce the rate of collagen synthesis [1];
- i. to reduce pruritus associated with immature hypertrophic scars [36]; and

j. to prevent the formation of contractures over flexor joints [63].

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