

## Fitted Pressure Garment of Assessment of Scar Thickness on Third-Degree Burns through Ultrasonic Measurement

Pi-Wen Huang<sup>1\*</sup>, Chih-Wei Lu<sup>1</sup> and Hsin-Liang Liu<sup>2</sup>

<sup>1</sup>Department of Industrial and Systems Engineering, Chung Yuan Christian University, Taiwan

<sup>2</sup>Department of Emergency Medicine, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Taiwan

### Abstract

The aim of this study was to assess the thickness of the scars on the left arm of a female third-degree burn patient through ultrasonic examination in order to investigate the use of 25-mm Hg pressure garments, which are a key treatment for burns. The patient was injured with third-degree burns more than 10 years ago. Sixteen scars were examined. The resulting Pearson correlation of the forearm and upper arm was 0.138 (weak correlation;  $R^2=0.0191$ ). Therefore, in this case, all data points fell on a straight line with a positive (upward) slope. This result indicated different thicknesses for the upper arm and forearm third-degree burn scars; this result displays different thickness for the upper arms and forearm the third degree burn scars; the scars did not spread evenly due to the loading capacity of different parts of body instead of the pressure by pressure garment.

This paper provides accurate information to manufacturers, therapists, and tailors regarding measurements for pressure garments. The results suggest that burn scars should be subject to appropriate pressure on the basis of medium scar height to avoid increasing scars and to stabilise burns, validating the hypothesis that 25 mmHg is not the optimal pressure for female patients with third-degree burns on the left arm and that the optimal pressure should be based on the patient's burns and wound area. To our knowledge, this is the first study to correlate the thickness of third-degree burns through ultrasound scan.

**Keywords:** Occupational therapists (OT); Hypertrophic scar (HS); Keloid; Total body surface area (TBSA); Rehabilitation; Pressure garments (PG); Vancouver scar scale (VSS); Ultrasound scan

### Introduction

All patients with burns over 20-25% (second degree) of the total body surface area (TBSA) develop systemic changes that influence their survival [1]. Asian skin is characterised by increased proliferation of fibroblast and more vigorous collagen formation, which results in prolonged erythema compared with Caucasian skin. Consequently, scars in most Asian patients require longer maturing [2,3]. Generally, wounds that do not heal within 2-3 weeks are considered most at risk for excessive scar formation [1,4-6]. Asians are more likely to develop hypertrophic scars compared with Caucasians, and Africans are more likely to develop hypertrophic scars than Asians [5,7]. Hypertrophic scarring is very common among the Chinese population [8]. In general, hypertrophic scarring occurs more frequently in women and patients of younger age groups [9].

Scars can be emotionally devastating, leading to mental and emotional complications. Scars can be disfiguring and aesthetically unpleasant. The side effects of scarring may include severe itching, tenderness, pain, sleep disturbances, anxiety, depression, and disruption of daily activities [5]. Scarring is a natural part of the healing process after an injury. Scar appearance and treatment depends on multiple factors, including wound depth, size, and location and the age, sex, ethnicity, and genetics of the patient. Types of scars include hypertrophic scars (HSs) and keloid scars [10,11].

HSs represent an abnormal, exaggerated healing response after skin injury. In addition to cosmetic concerns, scars may cause pain, pruritus, contractures, and other functional impairments [4,5,10,12-18]. Although hypertrophic scarring commonly occurs following burns, many aspects, such as its incidence and optimal treatment, remain unclear. After burn injury, they typically appear on the trunk and extremities. Frequently, HSs are misdiagnosed as keloids. Their

gross appearance is similar; however, keloids proliferate or originate beyond the wound margin [1,5,10,11,13,18,19].

The basic principle in scar treatment is applying constant pressure to the scars to occlude the capillaries and restrict oxygen availability to the affected region [7,20,21]. Minimising HS formation by creating a hypoxic condition results in focal degeneration of the perivascular particle cells and improves patients' range of movement [7,20-22].

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

Pressure garments have been the mainstay of HS and keloid treatment since the early 1970s. Although pressure garments are widely used, their efficacy has not been scientifically proven [16,23-26]. Many unanswered questions remain concerning their effective use and fabrication [16,23-30]. The garments must be worn 23 hours a day and removed for 1 hour for hygiene purposes, such as moisturising the skin or massaging the scar.

Scars must be moisturised once or twice a day with mild moisturiser and massage to soften the scars. Scars should be massaged firmly to

**\*Corresponding author:** Huang PW, Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chung Pei Road, Chung Li District, Taoyuan City, 32023, Taiwan, Tel: 886926627168; E-mail: [biwenannehuang@gmail.com](mailto:biwenannehuang@gmail.com), [biwen\\_anne\\_huang@yahoo.com.tw](mailto:biwen_anne_huang@yahoo.com.tw)

**Received** November 01, 2017; **Accepted** November 30, 2017; **Published** December 02, 2017

**Citation:** Huang PW, Lu CW, Liu HL (2017) Fitted Pressure Garment of Assessment of Scar Thickness on Third-Degree Burns through Ultrasonic Measurement. J Cytol Histol 8: 488. doi: [10.4172/2157-7099.1000488](https://doi.org/10.4172/2157-7099.1000488)

**Copyright:** © 2017 Huang PW, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

help disband the bundles of collagen within the scar. Massaging and applying skin creams can reduce any itching caused by the maturing scars [16,23-25,28,29]. Without the constant pressure of the garment, the collagen fibres of the scar tissue grow unsystematically, whereas the inner structure of a scar matured under constant pressure more closely resembles the natural patterns of fibres in healthy skin [20-22,26,31].

Burn scars are probably the scars with the highest impact on quality of life [17]. Both physical and psychological effects related to excessive scarring may hamper quality of life, including the often lengthy, painful treatment, which often provides only a suboptimal result [18,32]. Generally, a period where the pressure garment is worn for at least 6–18 months is required for burn scar maturation, at which time the redness (erythema) of the scar subsides, the scar no longer appears inflamed, and the scar contracture diminishes [15].

The following laboratory based on the patient's medical records and current status of the experiment.

## Methods and Materials

### Pressure garments

The pressure of the pressure garment was 25 mmHg made by the same pressure garment's manufacturer and tailors with the same materials as well as confirmed using the same pressure gauge which conditions are the same as the original pressure garment the patient wore in treatment. The pressure garment's was checked on a monthly basis to ensure consistent pressure.

### Ultrasound scans

Noninvasive skin thickness measurement has been proposed and

used clinically with varying degrees of success. This technique is useful not only for objective assessment but also for comparing two or more treatment techniques [7,22,33,34].

In this study, ultrasound measurements were conducted by an experienced medical Doctor who was trained to use this device by radiologists; ultrasound equipment (Philips HD15 Sonic CT) was used to measure the thickness of normal skin and scars.

### Patient and type of scars

The patient in the present study (age: 31 years old, sex: female, duration wearing pressure garment: 10 years) suffered second-to-third-degree burns to 77% of her TBSA and a level-1 inhalation injury; who started wearing pressure garment on the 92<sup>nd</sup> day of being injured. We examined the left arm and hand, which had third-degree burn injuries. On 27 December 2013 and 21 November 2014, 16 scars (eight flame-burned scars on the upper arm and eight flame-burned scars on the forearm) were quantitatively measured using ultrasound technology to determine their thickness and heights from the decade-old burn scar tissue. (Left arm: third-degree burns, MEEK split-thickness skin graft: 1:9, donor site: scalp).

### Procedure

Research data collection: Half an hour before scanning, the patient's pressure garments were removed. First, we used a marker to highlight the location of the scar from the upper arm to forearm (randomly) (Figures 1 and 2). Sufficient ultrasound gel was applied to mark a location between the ultrasound gel and the surface of the skin (Figure 2). The patient had 16 burn scars measured from the upper arm to outside elbow: deltoid to acromion 5 cm; distal to acromion scar

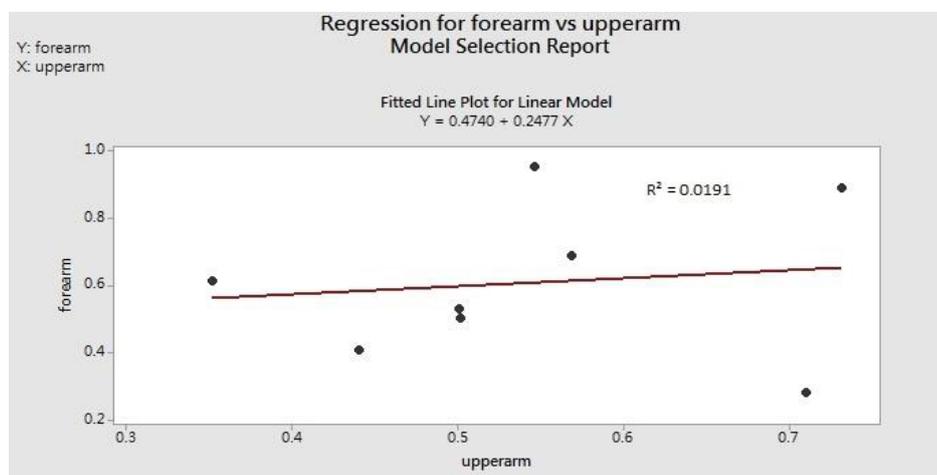


Figure 1: Regression for forearm v's upper arm model selection report. The result was a Pearson correlation of forearm and upper arm was 0.138. It indicated that there was a weak correlated with  $R^2=0.0191$ . Therefore, in the case, all of data fell on straight line with positive (upward) slope.



Figure 2: The marker pen indicates the order of the hand ultrasonic position. A sufficient amount of ultrasound gel was applied to mark a place between the water gel and the surface of skin. There were 16 flames, Burns measured from upper arm: elbow above, Deltoid, acromion 5 cm Distal, 3 cm distal to acromion scar, medial to Elbow 3 cm, medial to elbow 3 cm and forearm: Elbow crease, beneath the Medial elbow scar, Forearm Medial to Elbow 3 cm.

3 cm; medial to elbow 3 cm; medial to elbow 3 cm; forearm crease beneath the medial elbow scar (Figures 3 and 4); and forearm medial to elbow 3 cm (Figures 2 and 5).

Place and Operator: This experiment was conducted at Chang Gung Memorial Hospital, Taoyuan, Branch by Dr P.S Wu, who works in the Department of Physical Medicine and Rehabilitation Department.

### Data analysis

Descriptive statistics were used to describe scar thickness and prevalence for the sample measured through ultrasound scan. Statistical analysis was performed using Minitab v.17 for Windows, and interquartile ranges (IQR) and histograms were used to ascertain the difference in scar thickness between the upper arm and forearm.

### Results

The patient's 16 scars were measured on 23 August 2013 and 27 December 2014 (Figures 2-4); they were all significantly thicker than normal skin. The mean thicknesses of these 16 scars from the upper arm and forearm were 0.544 cm and 0.609 cm, respectively (Table 2). We determined that the thickness of normal skin was 0.15 cm through

an ultrasound scan in 2013 (Figures 2 and 3). The result was a Pearson correlation of forearm and upper arm of 0.138. It indicated a weak correlation with  $R^2=0.0191$ . Therefore, in the case, all the data fell on a straight line with a positive (upward) slope (Table 1 and Figure.1).

We determined that the statistical distribution of forearm burn scars was approximately 1.8 times (Table 2) greater than that of upper-arm burn scars; the difference between the standard deviation of the forearm and the upper arm and its mean forearm scarring value was considerable, but the upper-arm burn scars' height was within the limits of third-degree burns (Table 2, Figures 5 and 6).

Moreover, the interquartile ranges (IQR) of the upper arm and forearm were 0.220 cm and 0.406 cm, respectively (Figures 5, 6 and Table 3). The ranges for forearm scar thickness were almost twice those for upper-arm scar thickness; the median difference for both was 8.4% (Table 3): upper arm and forearm scar thicknesses were 0.5235 cm and 0.5715 cm, respectively. The upper-arm and forearm scar thickness IRQ had a difference of approximately 54%. The data were used to roughly estimate the degree of dispersion (Figure 5).

To sum up, upper arm was approximately 3.49 times and forearm was 3.81 times higher than the scar thickness for the normal skin which thickness was about 0.15 cm, respectively (Table 4).

### Discussion

This study validated the hypothesis that 25 mmHg is not the optimal pressure for female patients with third-degree burns on the left arm. According to previous statistical result, two factors are considered to reduce the function of 25 mmHg pressure garment for female patients with third-degree burns on the left arm, namely, the same pressure has different results on different body parts and errors of tailored measurement. Due to the previous discussion, we can confirm that burns at the same depth but on different body parts differ in scar thickness. This explain why some patients require silicone gel sheeting, massage, steroids, or presurgical skin graft, so minimal scarring results because identical pressure on different body parts has different results.

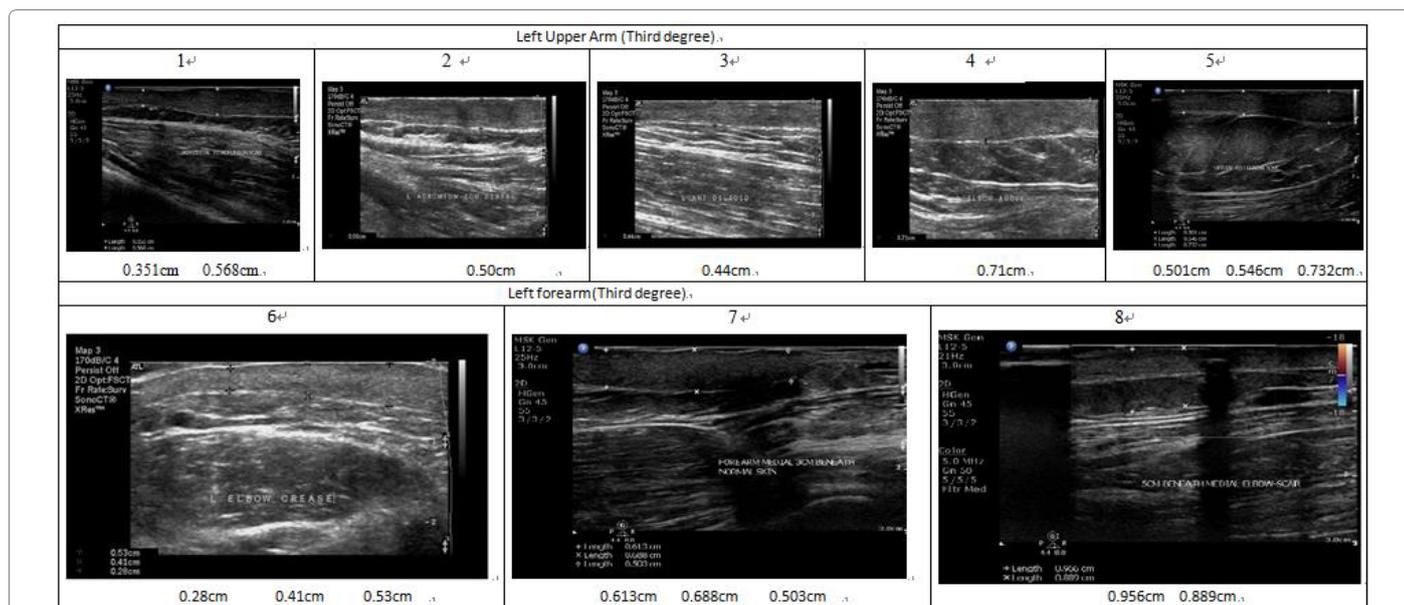
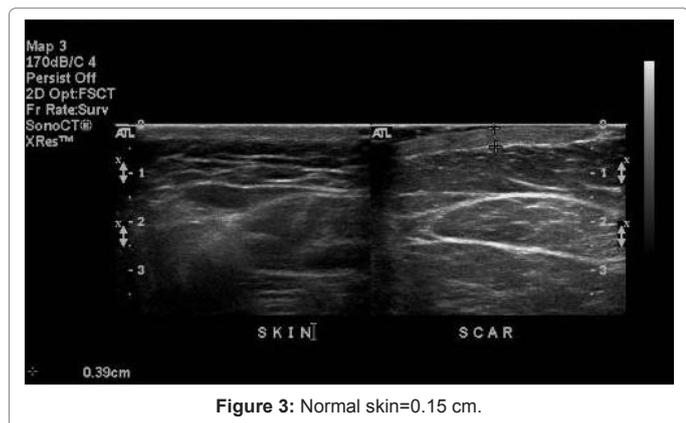


Figure 4: Thickness of the Third degree burns by record ultrasound measurement (on left hand) There were 16 flames, Burns measured from upper arm: elbow above, Deltoid, acromion 5 cm Distal, 3 cm distal to acromion scar, medial to Elbow 3 cm, medial to elbow 3 cm and forearm: Elbow crease, beneath the Medial elbow scar, Forearm Medial to Elbow 3 cm.

Term	Coef	SE	Coef	T-Value	P-Value	VIF
Constant	0.474	0.403	1.18	0.284		
Upper arm	0.248	0.725	0.34	0.744	1	

The result was a Pearson correlation of forearm and upper arm was 0.138. It indicated that there was a weak correlated with  $R^2=0.0191$ . Therefore, in the case, all of data fell on straight line with positive (upward) slope.

Table 1: Regression Equation  $Y=0.474 + 0.2477x$ .

Position	Mean	S.D.	S.E.M.	Median	Min	Max	N	Time
Upper arm	0.544	0.128	0.081	0.524	0.351	0.732	8	
Forearm	0.609	0.23	0.045	0.574	0.28	0.956	8	1.8

The mean of prominent scars of these 16 scars from upper arm was 0.544 cm and forearm was 0.609cm We found that the statistical distribution of forearm burn scars was approximately 1.8 times.

Table 2: Mean, Standard Deviation (S.D.), Standard error (S.E.) Median, minimum (Min) and maximum (Max) values for compression of 25mmHg(Scar thickness is calculated in centimeters).

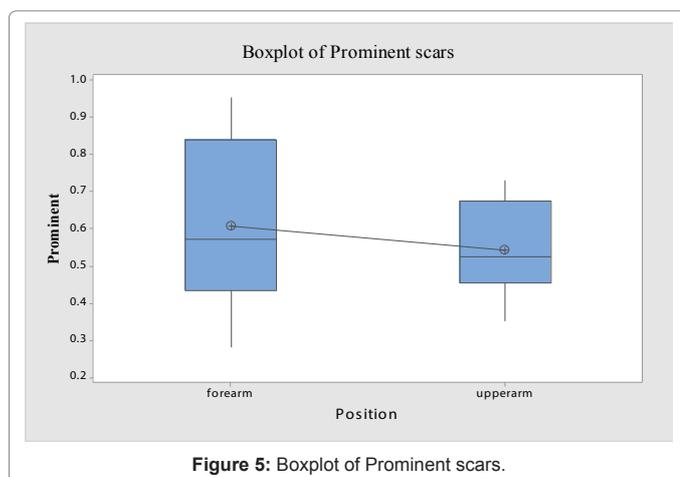


Figure 5: Boxplot of Prominent scars.

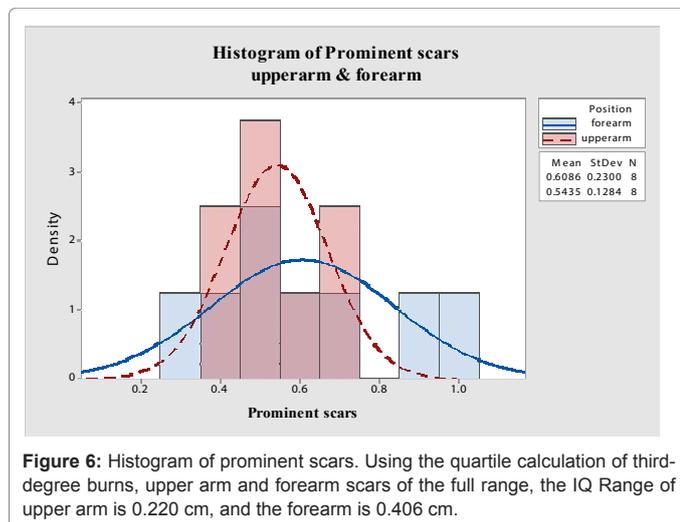


Figure 6: Histogram of prominent scars. Using the quartile calculation of third-degree burns, upper arm and forearm scars of the full range, the IQ Range of upper arm is 0.220 cm, and the forearm is 0.406 cm.

Therefore, the results of the paper suggest that burn scars should have appropriate pressure applied on the basis of the medium scar height to avoid an increase in the size of scars and to stabilise burns. Furthermore, many experts point out a fact that placing the human body in different postures affects the measurement results because of the difference of a cross-section and a straight section [35,36]. In skin surface contractility and extensibility during body movements, each point has a different maximum pull. This is particularly true of the hands, upper arms, elbows, and forearms; tension on these body parts

	Upperarm/cm	Forearm/cm	Percent
Q1	0.455	0.433	
Median	0.524	0.572	8.40%
Q3	0.675	0.839	
IQRange	0.22	0.406	54.00%

Table 3: Prominent scars of Checklist.

Normal skin/cm	Median/cm	Times
0.15	0.524	3.49
0.15	0.574	3.83

Using the quartile calculation of third-degree burns, upper arm and forearm scars of the full range, the IQRange of upper arm is 0.220 cm, and the forearm is 0.406 cm.

Table 4: Scar thickness comparison Table.

was particularly severe [36,37]. The same pressure (25 mmHg) applied to the upper-arm and forearm scars produced a considerable disparity. Therefore, this pressure was not the most suitable.

Although some experts have suggested applying pressure within a range of 15 mm Hg–25 mmHg [16,23,24,26,29,30,38-40], many experts have recommended wearing silica gel film inside the pressure garments (only at locations with hard or convex scars), but this type of silicon film can only be worn for 8-12 hours per day [6,12,14,41,42] because such items can lengthen scarring duration and can be allergenic. However, they still have a favourable effect.

This study investigated the ultrasound-measured thickness of 16 burn scars for a decade-old scar and analysed the association of thicknesses of these scar with the initial burn depth ascertained through ultrasound scan.

According to many studies, 25 mmHg is the optimal pressure for postburn pressure garments; however, these studies include only healthy human experiments and human machine model experiments [16,23,24,29,30].

In this study, the patient wore pressure garments of 25 mmHg from day 92 posttreatment (the patient did not leave the intensive care unit until day 86 posttreatment and was discharged with burns covering 9% TBSA). After 10 years, the median number of forearm scars was greater than the median number of upper-arm scars by 8% (Left arm: third-degree burns, MEEK split-thickness skin graft: 1:9, donor site: scalp.). The same pressure of 25mmHg was applied to the left-arm scars; upper-arm and forearm scar thicknesses were  $0.5235 \pm 0.128$  cm and  $0.609 \pm 0.230$  cm, respectively). However, the result mentioned above was weakly correlated.

## Conclusion

This paper is a valuable reference for occupational therapists and tailors who treat patients with large-area burns. This study was limited by the fact that it was based solely on one female patient. Future studies may include a greater number of participants. To sum up, this study validated the hypothesis that 25 mmHg is not the optimal pressure for female patients with third-degree burns on the left arm. Certificate of Approval: LSHIRBN o/Protocol: 17-010-B1.

## Conflicts of Interest

All authors declare no conflicts of interest.

## Acknowledgments

The authors express their deep appreciation to Dr S.S. Chuang of the Department of Plastic and Reconstructive Surgery, Dr P.S. Wu of the Department of Physical Medicine and Rehabilitation, Chang Gung Memorial Hospital, and Professor Shyi-Gen Chen M.D. MPH (National Defense Medical Center Tri-Service General Hospital) for instrument and general support medical knowledge.

## References

- Greenhalgh DG (2007) Chapter 46-Wound healing, *Total Burn Care* (3<sup>rd</sup>edn), p: 18.
- Anthonissen M, Daly D, Janssens T, Van den Kerckhove E (2016) The effects of conservative treatments on burn scars: A systematic review. *Burns* 42: 508-518.
- Kim CTS, Liu W, Ogawa R, Suh JS, Mustoe TA (2013) Update on scar management: guidelines for treating Asian patients. *Plast Reconstr Surg* 10.
- Dunne JA, Rawlins JM (2014) Management of burns Surgery. *Oxford* 32: 477-484.
- Frieri M, Kumar K, Boutin A (2016) Wounds, burns, trauma, and injury. *Wound Medicine* 13: 12-17.
- Monstrey S, Hoeksema H, Verbelen J, Pirayesh A, Blondeel P (2008) Assessment of burn depth and burn wound healing potential. *Burns* 34: 761-769.
- Cheng W, Saing H, Zhou H, Han Y, Peh W, et al. (2001) Ultrasound assessment of scald scars in Asian children receiving pressure garment therapy. *J Pediatr Surg* 36: 466-469.
- Candy LH, Cecilia LT, Ping ZY (2010) Effect of different pressure magnitudes on hypertrophic scar in a Chinese population. *Burns* 36: 1234-1241.
- Atiyeh EKAM, Dibo SA (2013) Pressure Garment Therapy (Pgt) Of Burn Scars: Evidence-Based Efficacy. *Annals of Burns and Fire Disasters* 26: 7.
- Chin GA, Mast BA (2006) Hypertrophic Scars and Keloids. *Current Therapy in Plastic Surgery* 6.
- Gauglitz GG, Korting HC, Pavicic T, Ruzicka T, Jeschke MG (2011) Hypertrophic scarring and keloids: pathomechanisms and current and emerging treatment strategies. *Mol Med* 17: 113-125.
- Arno AI, Gauglitz GG, Barret JP, Jeschke MG (2014) Up-to-date approach to manage keloids and hypertrophic scars: a useful guide. *Burns* 40: 1255-1266.
- Bayat A, Arscott G, Ollier WE, McGrouther DA, Ferguson MW (2005) Keloid disease: clinical relevance of single versus multiple site scars. *Br J Plast Surg* 58: 28-37.
- Bloemen MC, van der Veer WM, Ulrich: van Zuijlen MM, FB Niessen (2009) Prevention and curative management of hypertrophic scar formation. *Burns* 35: 463-475.
- Stappaerts EKK (2001) Silicones in the rehabilitation of burns: a review and overview. *Burns* 27: 9.
- Macintyre L (2007) Designing pressure garments capable of exerting specific pressures on limbs. *Burns* 33: 579-586.
- Cheng S, Fong S, Lam M, Leung A, Lee IP, et al. (1996) Outcome studies for burn patients in Hong Kong: patient's satisfaction. *Burns* 22: 4.
- Shaffer JJ, Taylor SC, Cook-Bolden F (2002) Keloidal scars: A review with a critical look at therapeutic options. *J Am Acad Dermatol* 46: 63-97.
- Zurada JM, Kriegel D, Davis IC (2006) Topical treatments for hypertrophic scars. *J Am Acad Dermatol* 55: 1024-1031.
- Eberlein WPA, Spilker G (2004) Compression therapy for burn injured patients. *Orthopädie-Technik*, 8.
- George Broughlon M (2005) Wounds and Scars, Selected readings in Plastic Surgery 10: 56.
- Wang XQ, Mill J, Kravchuk O, Kimble RM (2010) Ultrasound assessed thickness of burn scars in association with laser Doppler imaging determined depth of burns in paediatric patients. *Burns* 36: 1254-6122.
- Macintyre L, Baird M (2005) Pressure garments for use in the treatment of hypertrophic scars -- an evaluation of current construction techniques in NHS hospitals. *Burns* 31: 11-14.
- Macintyre L, Baird M (2006) Pressure garments for use in the treatment of hypertrophic scars--a review of the problems associated with their use. *Burns* 32: 10-15.
- Puzey G (2002) The use of pressure garments on hypertrophic scars. *Journal of Tissue Viability* 12: 11-15.
- Van den Kerckhove E, Stappaerts V, Fieuws S, Laperre J, Massage P, et al. (2005) The assessment of erythema and thickness on burn related scars during pressure garment therapy as a preventive measure for hypertrophic scarring. *Burns* 31: 696-702.
- Hamdiya A, Pius A, Ken A, Paa Ekow HW (2015) The trend of acute burns pre-hospital management. *Journal of Acute Disease* 4: 210-213.
- Lai CH, Li-Tsang CW (2009) Validation of the Pliance X System in measuring interface pressure generated by pressure garment. *Burns* 35: 845-851.
- Macintyre L (2011) New calibration method for I-scan sensors to enable the precise measurement of pressures delivered by 'pressure garments'. *Burns* 37: 1174-1781.
- Macintyre L, Ferguson R (2013) Pressure garment design tool to monitor exerted pressures. *Burns* 39: 1073-1082.
- Jeschke MG, Mlcak RP, Finnerty CC, Norbury W, Branski LK, et al. (2007) Burn size determines the inflammatory and hypermetabolic response. *Journal of Surgical Research* 137: 339-340.
- Mazharinia N, Shayan Z (2007) Dermatology Life Quality Index (DLQI) scores in burn victims after revival. *J Burn Care Res* 28: 312-317.
- Alexander H, Miller DL (1979) Determining Skin Thickness with Pulsed Ultra Sound. *Journal of Investigative Dermatology* 72: 17-19.
- Brusselsaers N, Pirayesh A, Hoeksema H, Verbelen J, Blot S, Monstrey S (2010) Burn scar assessment: A systematic review of objective scar assessment tools. *Burns* 36: 1157-1164.
- Lu JM, Wang MJJ, Mollard R (2010) The effect of arm posture on the scan-derived measurements. *Applied Ergonomics* 4: 236-241.
- Wang YJ, Mok PY, Li Y, Kwok YL (2011) Body measurements of Chinese males in dynamic postures and application. *Appl Ergon* 42: 900-912.
- Lin CL, Chen MS, Wei YL, Wang MJJ (2010) The evaluation of force exertions and muscle activities when operating a manual guided vehicle. *Applied Ergonomics* 4: 313-318.
- Li-Tsang CW, Feng B, Huang L, Liu X, Shu B, et al. (2015) A histological study on the effect of pressure therapy on the activities of myofibroblasts and keratinocytes in hypertrophic scar tissues after burn. *Burns* 41: 1008-1016.
- Maenthaisong R, Chaiyakunapruk N, Niruntraporn S, Kongkaew C (2007) The efficacy of aloe vera used for burn wound healing: a systematic review. *Burns* 33: 713-718.
- Ripper S, Renneberg B, Landmann C, Weigel G, Germann G (2009) Adherence to pressure garment therapy in adult burn patients. *Burns* 35: 657-664.
- Lee KC, Dretzke J, Grover L, Logan A, Moiem N (2016) A systematic review of objective burn scar measurements. *Burns Trauma* 4: 14.
- Monstrey S, Middelkoop E, Vranckx JJ, Bassetto F, Ziegler UE, et al. (2014) Updated scar management practical guidelines: non-invasive and invasive measures. *J Plast Reconstr Aesthet Surg* 67: 1017-1025.