Review Article

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USE OF SILICONE DRESSINGS IN POST-BURN HYPERTROPHIC SCAR THERAPY: A SYSTEMATIC REVIEW

Susanna Polotto

SUMMARY

Hypertrophic scarring is one of the most significant and frequent burn injury complications. Nowadays silicone dressings represent an effective therapy in their prevention and treatment. Mostly used in gel form, silicone dressings can be used either as pressure-associated or pressureless dressings, depending on the scar characteristics. Several hypotheses regarding silicone's active properties have been proposed in the literature and the most relevant seems to be its hydrating ability. Silicone dressings are reported to have low complication rates and do not require suspension therapy. The aim of this article is to show that silicone dressings are currently one of the first-step therapies to be applied in post-burn hypertrophic scar treatment, due to their proved efficacy on all scar parameters and subjective symptoms, in addition to their low complication rate.

Introduction

Since overall burn injury mortality has significantly decreased due to medical progresses and new treatments, aesthetic and functional outcomes have become more and more significant. This has promoted the development of new burn scar therapies. Burn scar management mainly aims at preventing local loss of function and non-cosmetic scars. Hypertrophic scarring is one of the most common complications and also one of the most difficult to treat. The natural healing process involves a scar formation process, i.e. a natural collagen deposition, and a re-epithelization process, which aims at restoring the injured skin's anatomical and structural integrity. Hypertrophic scarring is the result of an excessive response to a skin injury which usually occurs 6-8 weeks after the re-epithelization of a burn injury that has involved the reticular layer of the dermis. The main characteristics of this abnormal scar formation are: its red to deep purple colour, due to the enhanced and thick-walled microvascular proliferation in the injury site, which leads to a hypoxic granulation process, its elevation on the skin surface, its peculiarity of remaining within the original scar confines [1], its firmness, warmness, hypersensitiveness, which are sometimes associated with pain, and its itchiness. These pathological characteristics are the result of an overabundant deposition of collagen fibers performed by the fibroblasts during the proliferative phase of wound healing. After the burn scar maturation period (6 to 18 months, up to several years, depending on injury severity and potential wound healing process complications), the scar redness fades and other abnormal characteristics soften, as well. Several factors can affect the occurrence or the seriousness of post-burn hypertrophic scarring, both intrinsic, such as genetic predisposition, ethnicity, age, anatomical burn wound zone, burn wound depth, and extrinsic, such as local or systemic infections, prolonged immune responses, typology of wound heal-

Address of the author:
Plastic and Reconstructive Surgery Department, National Institute of Cancer Research (IST), University of Genoa , Italy

Send correspondence to: *Dr. Susanna Polotto, email: polotto.susanna@gmail.com*

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ing, previously applied therapies and local tensions. Hypertrophic scarring can cause important cosmetic disturbance and have an adverse effect on daily life, when contracture or pain problems are involved. Several therapies have been proposed to treat hypertrophic scars and their aim was to promote patients' psychological acceptance, social reintegration and functional recovery [2]. The most applied therapies, i.e. cortical steroid injection and surgical excision, comport notable side effects, such as localized sharp pain in the treated zone or high recurrence rate, depending on the different techniques or clinical methods used. The use of silicone dressings in post-burn hypertrophic scar prevention and treatment represents a non-invasive therapy which combines significant improvement scores with a very low complication rate. For this reason, the aim of this article is to provide a global view of the past and current literature on the use of silicone dressings, and to evaluate their mechanism of action and the possible future developments of these advanced dressings.

Typologies of silicone dressings in post-burn hypertrophic scar therapy

Silicone dressings are made of inert and mixed -inorganic and organic- polymers, which have a wide shape and application range. The most popular of them is polydimethylsiloxane, which is mostly used in silicone gel sheetings [3]. The first reports on silicone topical applications in post-operative care appear in literature from the 1950s [4, 5]; their qualities, such as stability and durability, immediately brought them to clinical attention. In wound therapy three typologies of silicone dressings are used: fluids, gel and elastomers.

Silicone fluids therapy was the first burn treatment used, as an immersion cure. It promoted a whole eschar separation, an early granulation tissue bed formation and an early joint motion. It was particularly effective in the treatment of hand-burn; nowadays its use has been abandoned.

Silicone elastomers and gel therapies make up one of the most successful and commonly used non-invasive topical techniques for post-burn hypertrophic scar treatment, often applied in association with pressure therapy. In particular, silicone gel sheetings constitute a soft, adherent, semi-occlusive garment, made up of cross-linked silicone polymers. The first therapeutic indications of the use of silicone gel sheetings on post-burn hypertrophic scars recommended its application at 6-8 weeks after burn injury, during the scar-development period [6], and an application time which should be at least 12 hours daily, in order to obtain the best results.

Silicone used as a pressure or pressureless dressing

Silicone dressings are used in two different forms of application [7]:

Silicone pressure dressings: several Authors [8, 9] have described the clinical benefits of the use of silicone elastomers as a pressure dressing, usually applied in combination with classical therapies. As a result of manufacturing improvements, these inserts can now be modeled perfectly to the most severely injured part, so that they can offer several benefits; such as a perfect injury fitting and an optimal solution for concave injury problems. Some disadvantages also exist; however, for example, they need changing often as the scar matures, mobility is lost when they are used on a joint, and healthy skin maceration may occur due to excessive sweating. Nevertheless, the combination of both the pressure and the optimal scar hydration provided by silicone dressings, which diminish the water vapor loss from the epidermis, provide for a significant improvement in all hypertrophic scar parameters.

Silicone pressureless dressings: these dressings consist of silicone sheetings, which might be silastic, i.e. elastomers, or gelsheets. They are both directly applicable to the scar without requiring any pressure and they have obtained similar clinical study results and therapy indications. Several Authors [6, 10, 11, 12, 13] have proposed the use of silicone gelsheets as an effective therapy for post-burn scars and of the most frequent burn injury complication, i.e. hypertrophic scarring. These clinical studies showed a significant improvement in the scar maturation process, as the silicone gel made scars more flexible and smooth. As well as the use of silicone gel sheetings as hypertrophic scar prevention and treatment [14, 15] their use has also been suggested for keloid prevention and treatment therapy [16, 17]. Another use for silicone gel sheetings was proposed by Sawada et al. [18], who gave them an additional drug-releasing skill by adding an antimicrobial agent, and used them in dermal-depth post-burn injury therapy. Furthermore, Palmieri et al. [19], added vitamin E to them for their use in hypertrophic scars and keloids therapy.

Main theories about silicone healing action

Several clinical studies have been performed with the aim of explaining the working mechanism of silicone gel sheeting in scar therapy. Among the first was Quinn et al. [20], who found no difference in the pressure applied, scar temperature and oxygen tension within the silicone-treated and non-treated scar groups. This clinical study suggested that the decisive factor determining significant scar improvement could be water vapor loss, which was estimated at half that normal skin in the silicone–treated group. This allowed the stratum corneum to provide a fluid reservoir which could help injury recovery. This evaluation may well be correct, since scar tissue has a greater transepidermal water vapor loss than the healthy epidermis; this consideration can also be applied to burn injuries, in which this loss can be increased up to 10 times [21]. Therefore, lowering water loss should make injured tissue more similar to healthy skin. Moreover, the stratum corneum of keloids or hypertrophic scars allows for increased water vapor evaporation from the epidermis barrier, if compared with a healthy skin barrier [22]. Furthermore, the reduction of water vapor loss leads to a capillary activity diminution, so that collagen deposition and consequent scar hypertrophy is also decreased [23]. An increased stratum corneum hydration is associated with a raised permeability of the skin towards water-soluble particles, so that cytokines and other inflammatory proteins migrate faster towards skin surface, thus helping hypertrophic scar maturation [24]. A clinical study on the effects of silicone gel sheetings on the stratum corneum of the epidermis, in hypertrophic scar and keloid therapy, compared the action of silicone gel sheetings with the action of a simple plastic film occlusion, demonstrating that silicone gel sheetings produced a favorable skin protecting condition and kept the stratum corneum in an adequate and not over-hydrated condition [25]. Another clinical study, in which silicone and non-silicone gel sheetings in hypertrophic scar and keloid therapy were compared, reported non-significant differences between the two groups, suggesting that the active principle of silicone gel sheetings could be hydration and occlusion related [26]. The hypothesis of the releasing in the stratum corneum of low molecular weight silicone particles, which could affect scar structure [12], also supported by the finding of silicone particles in some in vitro clinical studies biopsies [27], has more recently been called into question. In fact, no recent clinical study [28, 29] has found in vivo silicone particle penetration into scar tissue, or inflammatory response to a foreign body. Several Authors [18, 30] have claimed that despite silicone's principal therapeutic properties, such as occlusion and hydration, it is not silicone itself that is essential in producing clinical effects. This opinion is supported by the finding that it could just be the better hydration provided by silicone dressings which modulate the inhibiting effects of the keratynocytes on fibroblasts and not strictly the active principles of the silicone molecules [31]. In fact, keratynocytes need a hydrated environment to down-regulate the fibroblast collagen and glycosaminoglycan production. Furthermore, several Authors highlighted the main role of the epidermal processes in hypertrophic scar formation [32]. Significant cytokine mRNA changes, which symbolized tissue remodeling, were evidenced during hypertrophic scar therapy performed with both silicone and other occlusive dressing materials; these cytokine changes were mostly constituted by a significant IL8 drop, which is associated with a decreased erythema and a decreased water loss from the intravascular space, obtained by decreasing plasma leakage from acute wound [33]. Silicone gel affects epidermal properties, inhibiting mast cell activity and diminishing tissue oedema, vasodilatation and redundant extracellular matrix formation. These findings indicate that the most important action of silicone could be its ability to change basic scar temperature, pressure, oxygen tension and hydration, the beneficial effects of which are also due to a lowered tissue mechanical stress [34]. Nevertheless, the hydrating quality of silicone could also be provided for by a short-term topical tap water application to the injured skin, as it highly improves epidermis properties [35]. An opposite line of thought was offered by Hirshowitz et al. [36], who postulated that silicone gel sheetings could produce a static electric field, created by the silicone particles friction on skin surface, which might be the principal cause of the hypertrophic scar healing, as it influences the alignment of collagen fibers. Several Authors [37, 38] even proposed that the occlusion of healthy skin by garments enhances skin vascularization, damaging both the stratum corneum and its barrier function, and increasing skin pH, carbon dioxide emission and microbial flora. For these Authors the occlusion could be the active principle of the silicone gel sheeting therapy.

Alternative uses of silicone dressings

As well as basic silicone dressing therapies, several variants have been developed. The silicone elastomers manipulation technique can produce silicone dressings with a variable pressure degree, which are adaptable to all body sites [39]. Since its first applications [40], this technique has been extensively modified, leading to the development of inflatable silicone inserts, the pressure of which can be externally regulated by a pump. This dressing is particularly indicated for hypertrophic scars or keloids situated in concave areas or in soft tissue neck and face areas. Obviously, there are both advantages and disadvantages to combining silicone and pressure therapies. However, as a final outcome, each of these active principles, such as pressure, hydration, occlusion and static electricity, act to strengthen each other. Silicone can be also used in an innovative and simple fabrication technique in which oral splints are derived from silicone blocks. These could be used as post-operative pressure dressings for severe burn microstomia in children, following the surgical release and graft of anterior oral contractures [41]. Silicone splints have emerged as the simplest, easiest to fabricate, most easily available and suitable dressings for toothless children due to their softness and non-allergenic nature. Silicone dressings have also been proposed as a way of improve tissue expansion reliability in burn reconstruction [42]. Silicone gel sheetings, placed between the tissue expander and the skin surface, significantly decrease tissue erosion and consequent perforation, which are the most frequent complications of tissue expansion. Silicone dressing increases the surface area of maximal force exerted on the tissue substantially, dissipating the expansion force and preventing the focusing of erosive pressure on a single point. A new typology of advanced dressing is the Biobrane®, which is a semi-permeable silicone film with a nylon fabric and also has a porcine typology 1 collagen partially embedded into the film itself. The use of the Biobrane® is suggested for superficial partial thickness hand-burns; more specifically, Biobrane® gloves are used to facilitate its application and the specific burn therapy. Its main benefits are: pain reduction, no dressing changes, immediate hand mobilization and the possibility of a direct and continuous wound observation, due to the transparent dressing. The application of silicone gel sheetings on finger dorsum and web spaces is particularly useful if placed under the pressure garment glove, as they combine silicone and the pressure mechanism of action [43].

Complications in silicone dressings therapy

Some complications have been reported in several clinical trials which examined silicone gel sheetings' use. On the basis of a pediatric sample, Gibbons et al. [44] reported both negative results and complications, such as rash, skin breakdown, cessation of scar responsiveness to therapy, application problems and poor gel durability. Also other Authors [28, 12] highlighted a higher incidence of minor complications (rash, ulcer, erythema, pruritis) in the pediatric population, in association with pressure garments or adhesive tape used to keep the silicone gel sheetings in place. A higher complication rate in silicone gel sheeting therapy was also reported when used in post-burn hypertrophic scar management in Saudi Arabia's hot climate. The most frequent complications were persistent pruritis, skin breakdown, skin rash, skin maceration and a foul smell from the garments. Despite these minor complications, all but one patient completed the therapy, even though temporary treatment pauses and the appropriate hygiene measures were required [45]. The positive result of all these clinical studies was that all the complications disappeared when the therapy ended. Nevertheless, significant attention is advisable when adopting this therapy, since several Authors report a high complication rate, in up to 50% of the treated cases. A clinical study which examined the use of silicone gel sheetings in post-burn scar therapy, reported the rate of minor complications in adult patients as very low (7.5%) and not leading to therapy pauses, while it was higher in the pediatric patients (18%), even though only 6% of them had blistering and skin breakdown, which resulted in therapy discontinuation. As well as reporting better results in the silicone-treated group, a higher complication rate was not highlighted in the same group [46]. Finally, during a cytotoxicity test of burn wound dressings, ointments and creams, it has been shown that Mepitel®, a silicone wound contact layer, is not at all cytotoxic; this result placed silicone dressings among the most safe and non-reactive medical agents in use [47]. In conclusion, even though several clinical studies reported a high complication rate in silicone dressings therapy, these complications are all minor ones and do not compromise the scar healing process.

The benefits of the silicone dressings therapy

For the most part the literature sustains the benefits of silicone gel sheeting for both clinical parameters, such as scar colour, pliability and thickness, and subjective symptoms, such as local pain and itching, this is principally due to its hydration and pressure properties. A significant problem affecting scar therapy, which became immediately obvious to Authors, was the lack of treatment protocols, support therapies and even of standard measurement procedures, both in scar evaluation and in patients' subjective assessment of symptoms [48]; this has lead to a non-uniform appraisal of results. A randomized clinical trial, which investigated the effects of silicone gel sheetings (Cica-Care®) with associated massage therapy on severe post-traumatic hypertrophic scars, reported a significant scar thickness decrease at 2-months and 6-months post-intervention and also non-significant pigmentation, pain, itchiness and pliability improvement [49]. Another clinical study, which examined the silicone gel sheetings' mechanism of action in hypertrophic scar therapy, was based on the observation that the keratynocytes hydrating effect of the silicone gel had a suppressive effect on the fibroblasts metabolism, the result of which was a reduced collagen deposition and, then, a decreased dermal thickness. The scar elevation index (SEI) and the epidermal thickness index (ETI) were used to measure the scars; the first parameter was significantly reduced in the treated group while the second parameter was significantly increased in the untreated group. Thus, it was demonstrated that silicone gel treatment led to a significant epidermal thickness reduction, especially when its application started at a very early scar onset. An important finding of this clinical study could be the exclusion of silicone gel oxygen permeability as an important mechanism of action, because waterproofing the silicone dressing, thereby stopping the passage of oxygen, did not interfere with scar reduction [50]. Also Karagoz et al. [51] compared the efficacy of silicone gel (Scarfade®), silicone gel sheeting (Epi-Derm®) and topical onion extract including heparin and allantoin (Contractubex®) in burn hypertrophic scar therapy, using the Vancouver scar scale, which assesses the scar characteristics. This clinical study showed a statistically significant improvement in all treatments, even if the silicone dressings were highly superior to Contractubex®; this treatment did allow the plastic surgeon to select the most appropriate silicone gel dressing according to the patient's characteristics. Another clinical study, on the efficacy of silicone gel sheetings applied to post-burn hypertrophic scars, stands out in that clinical data and wound characteristics were collected by means of the Vancouver scar scale, which offers a uniform and objective standardization in scar evaluation. The results of this study showed that, although after 1 month of treatment all Vancouver scar scale measures were lower in the treated areas, only the vascularity parameter had significantly improved; at 4 months, all parameters, except for the pain score, (pigmentation, vascularity, pliability and itching) were significantly improved in the silicone treated area [52]; these results are also confirmed by other Authors [34]. A recent meta-analysis on silicone gel sheetings' efficacy in hypertrophic scar or keloid prevention or treatment established its effectiveness as a therapy for both [53]. Moreover, an international advisory panel has recommended silicone gel sheeting as a primary therapeutic option in hypertrophic and keloid scar prevention and treatment, thanks to its proved efficacy [54].

Conclusions

Nowadays it is possible to assert that silicone dressings, in the form of cream, gel sheeting, orthosis garments, etc., represent an indispensable therapeutic instrument in hypertrophic scarring prevention and treatment, especially after a burn injury. Their pressure, hydrating and occlusive properties are clinically effective on both objective and subjective scar symptoms; furthermore, silicone dressings are easy to manipulate, allowing the patient to have their very own personal dressing. Research into the active principle of the silicone derivates is currently being carried out; however, the two most acceptable hypotheses are the hydration of the epidermis stratum corneum and the creation of a static electricity field. It should also be noted that silicone dressings are often used in association with a pressure garment, thus combining both active principles. Another future objective is the development of a uniform assessment protocol, enabling the evaluation of both scar evolution and subjective symptoms, which would permit a standard evaluation in different clinical studies and allow for comparison of their results. A basic principle of silicone-based therapy is that hygienic measures are adhered to, in particular an initial treatment duration of only 12 hours a-day is important, especially when applied in combination with a pressure therapy, or on a pediatric population sample or in a warm climate [55, 45]. Hygienic measures should be taken to clean the silicone dressing and the healthy skin, thus avoiding its maceration. Regarding pressure as an active property of silicone dressings, it is has been confirmed that, despite sometimes provoking an increase in the complication rate, it usually leads to a major improvement in hypertrophic scar thickness. It also seems fundamental to apply pressure on burn injuries situated in anatomical areas where it is difficult to maintain the silicone gel sheetings in direct contact with the skin surface. Moreover, several Authors [56, 57] have supported the view that combining pressure and silicone therapies usually produces better results; for this reason, depending on the scar characteristic, the surgeon should evaluate the best therapeutic choice. This review on the current literature regarding the use of silicone dressings in post-burn hypertrophic scar therapy, aimed at providing a basis for further research on this topic and at stimulating further analysis of the current clinical data. The majority of clinical studies suggest that silicone dressings do have a significant therapeutic effect on hypertrophic scarring derived from burn injury and, given that it is a non-invasive therapy and easy to use, it should be the topic of further clinical studies.

References

1) Su CW, Alizadeh K, Boddy A, Lee RC: The problem scar. Clin Plast Surg 1998;25:451-465.

2) Mustoe TA, Cooter RD, Gold MH: International clinical recommendations on scar management. Plast Reconstr Surg 2002;110:560-571

3) Foo CW, Tristani-Firouzi P: Topical modalities for treatment and prevention of postsurgical hypertrophic scars. Facial Plast Surg Clin N Am 2011;19:551-557

4) Matzoni FA, Upchurch SE, Lambert CJ: An experimental study of silicones as a soft tissue substitute. Plast Reconstr Surg 1959;24:600-608

5) Brown JB, Ohwiler DA, Fryer MP: Investigation of and use of dementhyl siloxanes, halogenated carbons and polyvinyl alcohol as subcutaneous prostheses. Ann Surg 1960;152:534-547

6) Perkins K, Davey RB, Wallis K: Silicone gel: a new treatment for burn scars and contractures. Burns 1983;9:201-204

7) Perkins K, Davey RB, Wallis K: Current materials and techniques used in burn scar management programme. Burns 1987;13:406-410

8) Van den Kerckove E, Boeckx W, Kochuyt AM: Silicone patches as supplement for pressure therapy to control hypertrophic scarring. J Burn Care Rehabil 1991;12:361-369

9) Carr-Collins JA: Pressure techniques for the prevention of hypertrophic scars. Clin Plast Surg 1992;19:733-742
10) Davey RB, Bowering KA: Adhesive contact media – an update. Burns 1991;17:313-319
11) Quinn KJ, Evans JH, Courtney JM, Gaylor JDS, Reid WH: Non pressure treatment of hypertrophic scars. Burns 1985;12:102-108
12) Quinn KJ: Silicone gel in scar treatment. Burns 1987;13:S33-S34
13) Ahn ST, Monafo WW, Mustoe TA: Topical silicone gel for the prevention and treatment of hypertrophic scar. Arch Surg 1989;106:781-787
14) McNee J: The use of silicone gel in the treatment of hypertrophic scarring. Physiotherapy 1990;7:194-197
15) Ahn ST, Monafo WW, Mustoe TA: Topical silicone gel for the prevention and treatment of hypertrophic scar. Arch Surg 1991;126:499-504
16) Murdoch ME: Silicone gel in treatment of keloids. Acta Derm Venereol 1990;70:181-183
17) Gold MH: Topical silicone gel sheeting in the treatment of hypertrophic scars and keloid. J Dermatol Surg Oncol 1993;19:912-916
18) Sawada Y, Ara M, Yotsuyanagi T, Sone K: Treatment of dermal depth burn wounds with an antimicrobial agent releasing silicone gel sheet. Burns 1990;16:347-352
19) Palmieri B, Gozzi G, Palmieri G: Vitamin E added silicone gel sheets for treatment of hypertrophic scars and keloid. Int J Derm 1995;34:506-509
20) Quinn KJ, Evans JH, Courtney JM, Gaylor JDS, Reid WH: Non pressure treatment of hypertrophic scars. Burns 1985;12:102-108
21) Jelenko C: Studies in burns I. Water loss from the body surface. An Surg 1967;165:83
22) Suetake T, Sasai S, Zhen YX, Ohi T, Tagami H: Functional analyses of the stratum corneum in scars: sequential studies after injury and comparison among keloids, hypertrophic scars, and atrophic scars. Arch Dermatol 1996;132:1453-1458
23) Katz BE: Silicone gel sheeting in scar therapy. Cutis 1995;56:65-67
24) Beranek JT: Why does topical silicone gel improve hypertrophic scars? A hypothesis. Surg 1990;106:122
25) Suetake T, Sasai S, Zhen YX, Tagami H: Effects of silicone gel sheet on the stratum corneum hydration. British Journal of Plastic Surgery 2000;53:503-507
26) De Oliveira GV, Nunes TA, Magna LA, Cintra ML, Kitten GT, Zarpellon S: Silicone versus non silicone gel dressings: a controller trial. Dermatol Surg 2001;27:721-726
27) Shigeki S, Nobuoka N, Murakami T, Ikuta Y: Release and skin distribution of silicone-related compounds from a silicone gel sheets in vitro. Skin Pharmacol Appl Skin Physiol 1999;12:284-288
28) Ahn ST, Monafo WW, Mustoe TA: Topical silicone gel for the prevention and treatment of hypertrophic scar. Arch Surg 1991;106:781-787.
29) Fulton JE: Silicone gel sheeting for the prevention and management of evolving hypertrophic and keloid scars. Dermatol Surg 1995;21:947-951
30) Sawada Y, Sone K: Treatment of scars and keloids with a cream containing silicone oil. Brit J Plast Surg 1990;43:683-688.
31) Chang CC, Kuo YF, Chiu HC, Lee JL, Wong TW, Jee SH: Hydration, not silicone modulates the effects of keratynocytes on fibroblasts. J Surg Res 1995;59:705-711.
32) Andriessen MP, Niessen FB, Van de Kerkhof PC, Schalkwijk J: Hypertrophic scarring is associated with epidermal abnormalities. J Pathol 1998;186:192-200
33) Ricketts CH, Martin L, Faria DT, Saed GM, Fivenson DP: Cytokine mRNA changes during the treatment of hypertrophic scars with silicone and nonsilicone gel dressings. Dermatol Surg 1996;22:955-959
34) Chan KY, Lau CL, Adeeb SM, Somasundaram S, Nasir- Zahari M: A randomized, placebo controlled, double blind, prospective clinical trial of silicone gel in prevention of hypertrophic scar development in median sternotomy wound. Plast Reconstr Surg 2005;116:1013-1020
35) Jemec GB, Jemec B, Jemec BI, Serup J: The effect of superficial hydration on the mechanical properties of human skin in vivo: implications for plastic surgery. Plast Rec Surg 1990;85:100-106
36) Hirshowitz B, Ullmann Y, Har-Shai Y: Silicone occlusive sheeting (SOS) in the management of hypertrophic and keloid scarring, including the possible mode of action of silicone by static electricity. Eur J Plast Surg 1993;16:8-14.

37) Fluhr JW, Lazzerini S, Distante S, Gloor M, Berardesca E: Effects of prolonged occlusion on stratum corneum barrier function and water holding capacity. Skin Pharmacol Appl Skin Physiol 1999;12:193-198.
38) Aly R, Shirley C, Cunico B, Maibach HI: Effect of prolonged occlusion on the microbial flora, pH, carbon dioxide and transepidermal water loss on human skin. J Invest Dermatol 1978;71:378-381.
39) De Cubber J: A silicone elastomer manipulation technique for the production of medical devices. J Facial Somato Prosthetics 1998;4:15-21.
40) Van den Kerckhove E: Hypertofische wondheling en het belang van druktherapie. Woundcare Consultant Society-Nieuws 1992;2:49-56.
41) Al-Qattan MM, Rasool M, Al-Kattan W: Fabrication of silicone oral splints for severe burn microstomia in children. Burns 2005;31:217-219.
42) Borman H, Tufan H, Bilezikci B, Bahar T, Deniz M: Use of silicone sheet to improve the reliability of tissue expansion. Burns 2007;S33-S53.
43) Kamolz LP, Kitzinger HB, Karle B, Frey M: The treatment of hand burns. Burns 2009;35:327-337.
44) Gibbons M, Zuker R, Brown M, Candlish S, Snider L, Zimmer P: Experience with silastic gel sheeting in pediatric scarring. J Burn Care Rehabil 1994;15:69-73.
45) Nikkonen MM, Pitkanen JM, Al-Qattan MM: Problems associated with the use of silicone gel sheeting for hypertrophic scars in the hot climate of Saudi Arabia. Burns 2001;27:498-501.
46) Rayatt S, Subramaniyan V, Smith G: Letter to the Editor: Audit of receptions to topical silicon used in the management of hypertrophic scars. Burns 2006;32:653-654.
47) Kempf M, Kimble RM, Cuttle L: Citotoxicity testing of burn wound dressings, ointments and creams: a method using polycarbonate cell culture inserts on a cell culture system. Burns 2011;37:994-1000
48) Farquhar K: Silicone gel and hypertrophic scar formation: a literature review. Can J Occup Ther 1992;59:78-86.
49) Li-Tsang CWP, Lau JCM, Choi J, Chan CC, Jianan L: A prospective randomized clinical trial to investigate the effect of silicone gel sheeting (Cica-Care) on post traumatic hypertrophic scar among the Chinese population. Burns 2006;32:678-683.
50) Tandara AA, Mustoe TA: The role of the epidermis in the control of scarring: evidence for mechanism of action for silicone gel. Journal of Plastic, Reconstructive & Aesthetic Surgery 2008;61:1219-1225.
51) Karagoz H, Yuksel F, Ulkur E, Evinc R: Comparison of efficacy of silicone gel, silicone gel sheeting, and topical onion extract including heparin and allantoin for the treatment of postburn hypertrophic scars. Burns 2009;35:1097-1103.
52) Momeni M, Hafezi F, Rahbar H, Karimi H: Effects of silicone gel on burn scars. Burns 2009;35:70-74.
53) O'Brien L, Pandit A: Silicon gel sheeting for preventing and treating hypertrophic and keloid scars. Cochrane Database Syst Rev 2006;1:CD003826.
54) Mustoe TA, Cooter RD, Gold MH: International clinical recommendations on scar management. Plast Reconstr Surg 2002;110:560-571.
55) Van de Kerckhove E, Stappaerts K, Boeckx W, Van Den Hof B, Monstrey S, Van der Kelen A, De Cubber J: Silicones in the rehabilitation of burns: a review and overview. Burns 2001;27:205-214.
56) Berman B, Bieley HC: Adjunct therapies to surgical management of keloids. Dermatol Surg 1996;22:126-130.
57) Berman B, Flores F: The treatment of hypertrophic scars and keloids. Eur J Dermatol 1998;8:591-596.