Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/burns

Evaluation of scar quality after treatment of superficial burns of the hands and face with Dressilk or Biobrane—An intra-individual comparison

Jennifer Lynn Schiefer [a,*], Rebekka Rath [b], Elena Ahrens [a], Daniel Grigutsch [c], Ingo Gräff [c], Jan-Philipp Stromps [a], Paul Christian Fuchs [a], Alexandra Schulz [a]

[a] Clinic of Plastic, Reconstructive, Hand and Burn Surgery, Hospital Cologne Merheim, University of Witten-Herdecke, Germany

[b] Clinic for Hand and Plastic Surgery, Orthopedic Clinic Markgröningen, Germany

[c] Clinic of Anesthesiology at the University Hospital Bonn, Germany

ARTICLE INFO

Article history:
Accepted 28 July 2017

Keywords:
Scar evaluation
Scar quality
Burn wound
Dressilk
Silk
Biobrane
Superficial burn
Skin elasticity

ABSTRACT

Introduction: The aesthetic outcome after burn of exposed areas such as the hand and face is of high importance. A number of wound dressings used for the treatment of superficial and partial thickness burns promise rapid wound healing and reduced scarring. Previously, wound healing of hands and faces with superficial burns treated with Dressilk® compared to Biobrane® was evaluated intra-individually with similar results. Nevertheless, up to date objective information regarding the scarring after superficial burns treated with Dressilk® does not exist.

Methods: Therefore, 30 patients with superficial burns of the hand and face that were treated with Dressilk® and Biobrane® simultaneously were included in the study. An objective scar evaluation was performed analyzing melanin and erythema levels, skin elasticity, trans-epidermal water loss and scar perfusion three and six and 12 months after injury. Furthermore, a subjective scar evaluation was performed with the patient and observer scar assessment scale (POSAS) and the Vancouver scar scale (VSS).

Results: Dressilk® and Biobrane® both lead to an aesthetic pleasing outcome after superficial burns of the hands and faces. Regarding the objective scar evaluation only trans-epidermal water loss of burned hands after 6 months showed significant differences between the two dressings. However, these differences were not detected in the 12-month follow up examination. In the subjective scar evaluation no statistical differences could be found between the dressings. All patients stated high satisfaction of scar quality.

Conclusion: Dressilk® is an interesting alternative to Biobrane® for the treatment of superficial burns of aesthetic and functional important areas.

* *Corresponding author at*: Clinic of Plastic, Reconstructive, Hand and Burn Surgery, Hospital Cologne Merheim, Ostmerheimer Strasse 200, 51109 Cologne, Germany.
E-mail address: schiefer.jennifer@gmail.com (J.L. Schiefer).

http://dx.doi.org/10.1016/j.burns.2017.07.024
0305-4179/

1. Introduction

As scars especially of exposed areas like the hand and face are visible for everybody aesthetic outcome usually is of high importance to patients. Lawrence et al. showed in a survey with 361 burned patients a correlation between visible scarring and different aspects of the body esteem [1]. Moreover, he proved that visible scarring is associated with greater distress and is correlated with perceived stigmatization.

Furthermore, functionality especially of the hands needs to be preserved after burn. Post burn scar contractures can limit hand function and herewith activities of daily life [2]. Therefore, both scarring and functionality of post burn wounds, need to be evaluated in the long term. Up to date there is a lack of studies focused on the objective evaluation of scarring after burn treatment [3,4]. A number of wound dressings used for the treatment of superficial and partial thickness burns promise a fast wound healing and reduced scarring. There are many different wound care materials for the treatment of burn wounds. Directors of burn centers around the world understandably enough prefer tested “tried and true” material over newer dressings [5]. Nevertheless, there is a high quest finding functional and cost-efficient dressings.

Biobrane® (Smith and Nephew, United Kingdom) is a widely used [3,6–8] temporary wound dressing firstly introduced in 1979 [9,10]. It is a bio-composite dressing made from an ultrathin, semipermeable silicone membrane mechanically bonded to a flexible knitted tri-filament nylon fabric with porcine collagen type I [9]. It is able to temporarily substitute the epidermis and can be used for the treatment of superficial partial thickness to mid-dermal burns after early debridement as well as deep dermal and full thickness burns as long as autograft is unavailable or for graft reduction in areas where burn depth is unclear [9]. The nylon mesh peels of gradually when the new epidermis underneath is built. Biobrane® is often used for the treatment of superficial burns requiring a fast wound healing and reduced scarring [3,6,7]. Williams for instance proofed in a study about physical and quality of life after isolated hand burn of 52 patients that treatment with Biobrane® showed normal or near-normal values after 2 weeks to 1 months concerning pain, return to work/leisure, total active range of motion, grip strength and scar appearance [11]. Biobrane® used to be the standard treatment of superficial burns in our clinic. However delivery problems urged us to look for a functional and cost efficient alternative. In former studies pleasing results were found in the treatment of skin graft donor sites with silk.

Dressilk® (Prevor, France) consists of fibroin silk produced by silkworms. Silk as a relatively new biomaterial for wound dressings shows high potential [12–16]. It is proven to show less inflammation and better regeneration of collagen compared to hydrocolloids [17,18]. Furthermore, it has been tested in an animal model to work together with colistin effectively against wound infection [19]. Moreover, silk is semi transparent, which simplifies observation, is sterilizable and convinces with a reasonable price due to low production costs [18,20]. Costs for Biobrane® were approximately ten times higher than for Dressilk® in our clinic.

Therefore, we had decided to conduct a study comparing natural silk to Biobrane® in the treatment of superficial burns previously. Application did not differ between the two materials. Results regarding inflammation, pain, exudation and time to wound healing were pleasing, leading to a high subjective patient satisfaction [21].

Nevertheless, up to date no data evaluating the scarring after treatment of superficial burns of the hand or face with silk can be found. Therefore, we evaluated the long term scarring of the hand and face after treatment of superficial burns with Biobrane® and Dressilk®.

2. Methods

The present study evaluated the scarring of superficial burn wounds on the hand and face after treatment with Biobrane® and Dressilk®. Previously it had been reviewed and approved by the Ethical Review Committee of the University of Witten Herdecke, Germany (protocol number 35/2015) according to the declaration of Helsinki. Complete informed consent was obtained from all patients. A total number of 30 patients with superficial burns of the hand or face had been treated with Biobrane® and Dressilk® in an intra-individual study design. After inclusion in the study the burned wound had been debrided and cleaned according to our standard of care (SOC). Afterwards, half of the burn wound had been treated with Dressilk® and the other half with Biobrane®.

Then, 6 and 12 months later scar formation was evaluated in regard to (a) melanin and erythema level, (b) skin elasticity, (c) trans-epidermal water loss (TEWL), (d) scar perfusion, (e) patient and observer scar assessment scale (POSAS) and (f) the Vancouver scar scale (VSS). Furthermore, all scars were documented by standardized digital photography imaging.

2.1. Patients

During April 2015 and November 2015, 30 patients with superficial burns had fulfilled the inclusion criteria and were enrolled in the study. According to the treatment protocol they had superficial burns of more than 0.5% of the body surface area, were at least 18 years old and had agreed to be treated with both dressings simultaneously.

2.2. Scar evaluation

Follow-up examinations were performed 6 and 12 months after treatment. All follow-up examinations were performed in the same assessment room in a standardized manner. Patients were first placed physically inactive for at least 20 min. Treatment areas were identified on the basis of digital photo documentation taken post intervention. First scar quality was evaluated following POSAS and VSS individually. Thereafter, in order to minimize the inter-observer error, all measurements were taken by the same experienced user. Probes were held perpendicular to the skin while minimal pressure was applied to avoid skin or scar blanching. All measurements were performed three times.

2.2.1. Subjective evaluation tools

The POSAS is one of the only scar assessment tools that includes scar evaluations of patients and physicians. Due to this the POSAS has been proven to be feasible, effective and reliable in many studies. The VSS is a traditional validated and often used subjective scale for scar assessment.

2.2.2. Objective evaluation tools

Tools for the objective scar assessment of scar formation are rare. Mexameter®, Tewameter® and Cutometer® (Courage +Khazaka electronic GmbH, Germany) are commercial non-invasive, in-vivo diagnostic devices which have been widely used in various research studies. Additionally, superficial oxygen saturation (SO2), hemoglobin concentration (rHb) and blood flow measurements were evaluated by means of the O2C device (LEA Medizintechnik GmbH, Germany).

2.3. Erythema and melanin

Optimal assessment to assess skin color is spectrophotometric, based on the reflection and absorption of light [22]. This can be carried out by a Mexameter® MX 18 (Courage +Khazaka electronic GmbH, Germany) that has proven good intra-observer and inter-observer reliability in scar assessment [23]. Through measurements of melanin and erythema level differences in erythema or pigmentation can be shown. Melanin and the severity of erythema in the skin are measured in a relative unit of A.U., ranging from 0 to 999. Higher values indicate a higher level of melanin deposition and erythema.

2.4. Viscoelasticity and pliability

Skin elasticity measurements with the Cutometer® dual MPA 580 (Courage+Khazaka electronic GmbH, Germany) are proved to be highly reliable and reproducible for burn scars [22–25]. This tool uses a suction extension method. The degree of elasticity of the skin is defined as the maximum value of skin distortion caused by constant suction pressure (400 mbar) for three seconds by the Cutometer®. Skin deformation can be measured by this optical system up to an accuracy of 0.10 mm. Parameters of highest reliability are Ue and Uf [23,24]. Uf = "Extension" and relates to the firmness of skin. It is automatically calculated by the computer software and represents the passive behavior of the skin to force. Lower values represent higher firmness.

Ue = "Elasticity" and is calculated through the total deviation of the skin x relaxation time/(max. amplitude × time). Lower values represent more elastic skin.

2.5. Trans-epidermal water loss (TEWL)

The water content of the skin significantly contributes to its softness. Burn damages the lipoprotein complex in the stratum corneum of the skin as its barrier [26]. This leads to an increased evaporative water loss and decreased skin-moisture [22,26], which can be measured with a Tewameter® 580. In an open chamber system two pairs of sensors measure temperature and relative humidity. The trans-epidermal water loss is described as SSWL (Skin Surface Water Loss) (g/m^2).

Fig. 1 – (A) Superficial burn of the hand, (B) treatment with Biobrane® and Dressilk® simultaneously, (C) scar evaluation after 6 months, D: scar evaluation after 12 months.

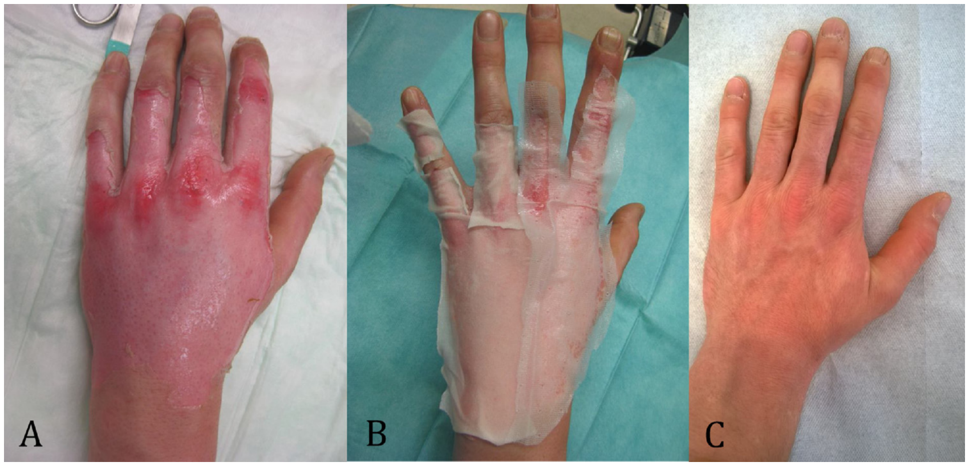

Fig. 2 – (A) Superficial burn of the hand, (B) treatment with Biobrane® and Dressilk® simultaneously, (C) scar evaluation after 12 months.

2.6. *Laser tissue oxygen saturation, hemoglobin level and microcirculation*

O2C is a laser based method assessing the microcirculation in the scar, which influences erythema as well as functionality of the scar [23]. It combines white light tissue photo spectroscopy (detection range: 450–850 nm; resolution: 1 nm) and laser-doppler examination (wavelength: 830 nm; power: <30 mW). Thus superficial oxygen saturation (SO2), relative amount of hemoglobin (rHb) (as a marker of venous filling) and blood flow are measured in real time.

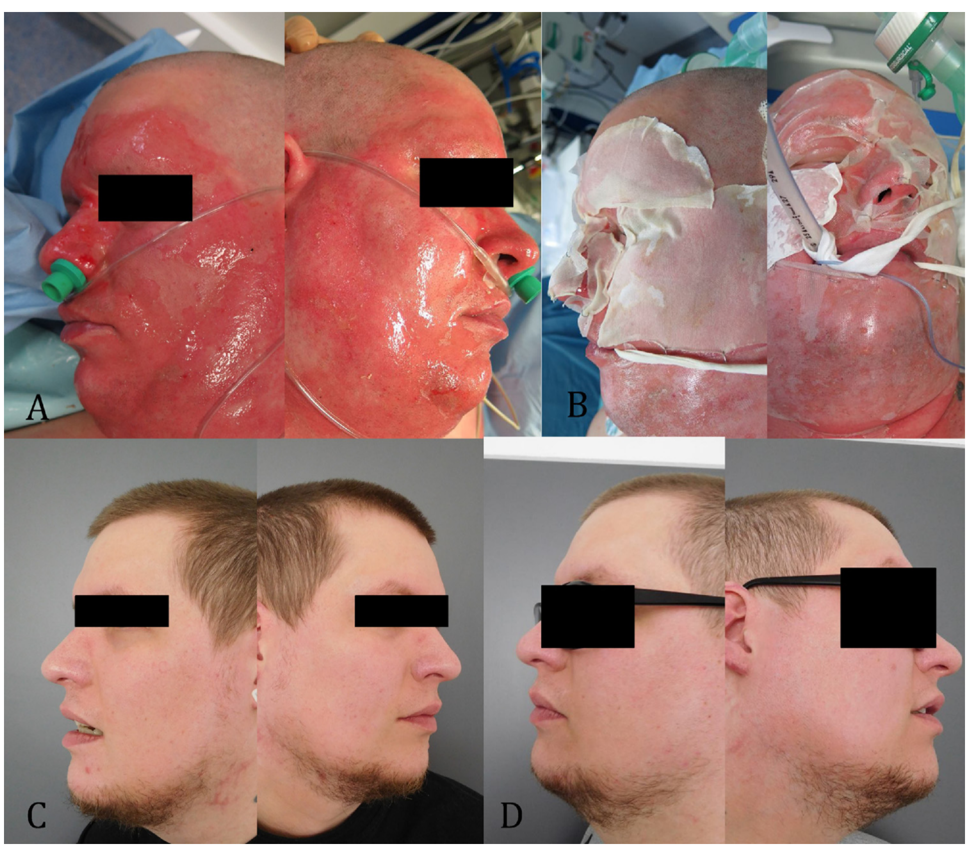

Fig. 3 – (A) Superficial burn of the face, (B) treatment with Biobrane® and Dressilk® simultaneously, (C) scar evaluation after 6 months, D: scar evaluation after 12 months.

2.7. Statistical analysis

We used Microsoft Excel (2013, Microsoft, USA) to manage data and design the charts. Prior analysis data were checked for completeness and accuracy checks were conducted. Final analysis was performed with SPSS (IBM, USA) Version 21. The data was collected prospectively. All three paired samples were analyzed for statistical significant differences first by Friedman test. In case of significant differences, we used Wilcoxon test for pair-wise comparisons. Statistical significance was accepted at p-values <0.05.

3. Results

Altogether 30 patients were treated with Biobrane® and Dressilk® simultaneously as already reported [21] and now included in the follow-up evaluation (Figs. 1–3). All patients took part at the follow up examination after 6 months, 18 patients also took part in the follow-up examination after 12 months. Thus, we assessed no dropouts after 6 months and data was found to be complete for all enrolled patients. Unfortunately, we had 12 dropouts after 12 months, especially patients living further away from the hospital. All patients were males; no females were included in the study. Their age ranged from 19 to 52 with a mean of 37.2 years. All patients were treated after superficial burns of the face and hands. Thereof 15 patients had a burn of the face and 15 patients a burn of the hand.

3.1. Results of the subjective scar evaluation (VSS and POSAS)

3.1.1. VSS after 6 and 12 months

After 6 months no differences regarding pigmentation, vascularity, pliability and height could be found between treated and untreated areas as well as between areas treated with different dressings. The measurements performed after 12 months revealed the same results (Tables 1–3).

3.1.2. Patient scar scale (PSAS)

After 6 months the results of the PSAS referring the treated area hand showed significant differences between Biobrane®/untreated skin and Dressilk®/untreated skin regarding the hand, but no significant differences between the two dressings themselves (Table 1). After 12 months differences could be detected, but they were not significant even when comparing the treated and the untreated areas (Table 2). The results of the

Table 1 – Results of the subjective scar evaluation of the hand (n=15) after 6 months with the VSS and POSAS. Pairwise comparison between Dressilk, Biobrane and untreated skin. Overall p value based on Friedman's test for the three groups, pairwise comparison based on Wilcoxon rank sum test for paired data (statistical significant data marked).

	Hand			
	Overall (p Values of Friedman's Test)	Biobrane/Dressilk (Wilcoxon test)	Biobrane/untreated skin (Wilcoxon test)	Dressilk/untreated skin (Wilcoxon test)
VSS				
Pigmentation	0.097	–	–	–
Vascularity	0.368	–	–	–
Pliability	0.368	–	–	–
Height	0.368	–	–	–
POSAS patient scale				
Pain	0.607	–	–	–
Itching	0.102	–	–	–
Scar	0.010	0.928	0.027	0.007
Stiffness	0.223	–	–	–
Thickness	0.223	–	–	–
Irregularity	0.009	0.778	0.017	0.017
Overall	0.010	0.927	0.017	0.007
POSAS observer scale				
Vascularity parameter	0.007	1.000	0.034	0.034
Vascularity category	0.001	1.000	0.016	0.016
Pigmentation parameter	<0.001	0.317	0.007	0.004
Pigmentation category	<0.001	0.317	0.010	0.006
Thickness parameter	0.050	1.000	0.102	0.102
Thickness category	0.368	1.000	0.131	0.131
Relief parameter	0.018	1.000	0.066	0.066
Relief category	<0.001	0.317	0.010	0.006
Pliability parameter	0.050	1.000	0.102	0.102
Pliability category	0.050	1.000	0.083	0.083
Surface area parameter	0.050	1.000	0.102	0.102
Surface area category	0.050	1.000	0.102	0.102
Overall opinion parameter	0.001	1.000	0.016	0.016

Table 2 – Results of the subjective scar evaluation of the hand (n=10) after 12 months with the VSS and POSAS. Pairwise comparison between Dressilk, Biobrane and untreated skin. Overall p value based on Friedman's test for the three groups, pairwise comparison based on Wilcoxon rank sum test for paired data (statistical significant data marked).

	Hand			
	Overall (p Values of Friedman's Test)	Biobrane/Dressilk (Wilcoxon test)	Biobrane/untreated skin (Wilcoxon test)	Dressilk/untreated skin (Wilcoxon test)
VSS				
Pigmentation	0.018	1.00	0.063	0.063
Vascularity	0.368	–	–	–
Pliability	0.368	–	–	–
Height	0.368	–	–	–
POSAS patient scale				
Pain	0.368	–	–	–
Itching	0.368	–	–	–
Scar	0.135	–	–	–
Stiffness	0.135	–	–	–
Thickness	0.368	–	–	–
Irregularity	0.135	–	–	–
Overall	0.05	1.00	0.109	0.109
POSAS observer scale				
Vascularity parameter	0.135	–	–	–
Vascularity category	0.018	1.00	0.066	0.066
Pigmentation parameter	0.050	1.00	0.102	0.102
Pigmentation category	0.018	1.00	0.063	0.063
Thickness parameter	0.135	–	–	–
Thickness category	0.050	1.00	0.063	0.063
Relief parameter	0.050	1.00	0.102	0.102
Relief category	0.018	1.00	0.066	0.066
Pliability parameter	0.135	–	–	–
Pliability category	0.050	1.00	0.102	0.102
Surface area parameter	0.135	–	–	–
Surface area category	0.050	1.00	0.109	0.109
Overall opinion parameter	0.050	1.00	0.109	0.109

PSAS after 6 and 12 months referring the treated area face showed no significant differences between treated and untreated areas (Table 3).

3.1.3. *Observer scar scale (OSAS) after 6 months*

After 6 months the results of the OSAS referring the hand showed significant differences between Biobrane®/untreated skin and Dressilk®/untreated skin regarding relief and pigmentation but no significant differences between the two dressings themselves (Table 1). After 12 months no significant differences could be detected (Table 2). The results of the OSAS after 6 and 12 months referring the treated area face showed no significant differences between treated and untreated areas (Table 3).

3.2. *Results of the objective scar evaluation*

3.2.1. *Mexameter after 6 and 12 months*

The results of the Mexameter® measurements of the hand showed significant differences regarding the erythema level between the treated and untreated areas of the face after 6 months (Tables 4 and 6). Hereby the initially burned and treated areas showed a higher erythema level compared to the untreated and uninjured skin. The face showed no significant differences between the treated and non-treated areas (Table 5). After 12 months no significant differences could be detected (Table 8).

3.2.2. *Tewameter® after 6 and 12 months*

After 6 months significant differences between Biobrane® and Dressilk® (p=0,008) could be found after treatment of the hand (Table 7). Altogether the Tewameter measurement revealed higher values after treatment with Dressilk® compared to areas treated with Biobrane®. In the face also significant higher values could be detected after treatment with Dressilk® compared to the untreated skin (p=0,026). Nevertheless, no significant differences between the two dressings could be found in the face (Tables 4 and 5).

After 12 months no significant differences could be found (Table 8).

3.2.3. *Cutometer® after 6 and 12 months*

The results of the Cutometer® measurements of the hand and face showed no significant differences between the treated and non-treated areas regardless of the applied dressing (Tables 4, 5 and 8).

3.2.4. *O2C after 6 and 12 months*

The results of the O2C measurements of the hand and face showed no significant differences between the treated and

Table 3 – Results of the subjective scar evaluation of the face after 6 months (n=15) and 12 months (n=8) with the VSS and POSAS. Pairwise comparison between Dressilk, Biobrane and untreated skin. Overall p value based on Friedman's test for the three groups (no statistical significant data).

	Face				
	Overall after 6 months (p Values of Friedman's Test)	Overall after 12 months (p values of Friedman's Test)	Biobrane/ Dressilk (Wilcoxon test)	Biobrane/untreated skin (Wilcoxon test)	Dressilk/untreated skin (Wilcoxon test)
VSS					
Pigmentation	0.368	1.000	–	–	–
Vascularity	1.000	1.000	–	–	–
Pliability	1.000	1.000	–	–	–
Height	1.000	1.000	–	–	–
POSAS patient scale					
Pain	0.368	1.000	–	–	–
Itching	1.000	1.000	–	–	–
Scar	1.000	1.000	–	–	–
Stiffness	1.000	1.000	–	–	–
Thickness	1.000	1.000	–	–	–
Irregularity	1.000	1.000	–	–	–
Overall		1.000			
POSAS observer scale					
Vascularity parameter	1.000	1.000	–	–	–
Vascularity category	0.368	0.368	–	–	–
Pigmentation parameter	1.000	1.000	–	–	–
Pigmentation category	0.368	0.368	–	–	–
Thickness parameter	1.000	1.000	–	–	–
Thickness category	0.368	0.135	–	–	–
Relief parameter	1.000	1.000	–	–	–
Relief category	0.368	0.368	–	–	–
Pliability parameter	1.000	1.000	–	–	–
Pliability category	0.368	0.368	–	–	–
Surface area parameter	1.000	1.000	–	–	–
Surface area category	1.000	0.368	–	–	–
Overall Opinion parameter	1.000	1.000	–	–	–

non-treated areas regardless of the applied dressing (Tables 4, 5 and 8).

4. Discussion

Facial deformities as caused by scars have a negative effect on perceptions of social functionality [1,27] and may disrupt the body image of the person itself [28]. Therefore, cosmetic appearance of a scar in this area is of high importance to the patients. Moreover, hand burns can have a negative impact on patients' life quality not only through appearance but also through limited function [11]. Scars show different color, texture, elasticity and trans epidermal water loss compared to normal skin [23,29,30].

However, superficial second degree burn wounds are known to heal within two to four weeks without or with minimal scarring assuming that appropriate local wound care is provided and infection prevented [2,29,31–33]. Modern biosynthetic wound dressings are additionally assumed to accelerate wound healing [34,35] and herewith minimize scarring [36–38].

In our study we found differences six months after treatment between initially burned areas and normal skin regardless of the applied wound dressing. Up to date the relationship between depth of injury and scarring remains unclear [39]. Dunkin et al. showed in a dermal scratch model that scarring occurs at a critical depth somewhere between superficial dermal and deep dermal [39]. He detected scarring in terms of visible scarring using digital photography as well as high-frequency ultrasound scanning [39]. It is known that the epidermis is capable of regenerative healing [40], meaning, that it is able to rebuild the exact same structure. Therefore, superficial wounds (involving the epidermis solely) heal without scarring. In contrast to this deep dermal burns always heal with scarring [40]. Superficial partial thickness burns affecting the epidermis and top third of the dermis [29] are known to lead to different skin pigmentation [40,41].

Skin color- In this study we found pale scars in the face after only 6 months. Scar appearance is strongly influenced through pigmentation and erythema [23]. However, color observation and reporting is often difficult for a human observer [23]. This can be objectified through measurements with the mexameter® and the O2C. Mexameter® measurements are

Table 4 – Results of the objective scar evaluation of the hand after 6 months.

Objective scar evaluation of the hand after 6 months

	O2C SO2	O2C Hb	O2C Flow	Mexa-meter Mean Melanin	Mexameter Mean Erythem	Tewa-meter Standard AW	Tewa-meter TEWL	Tewa-meter Mean	Cuto-meter R 0	Cuto-meter R 2	Cuto-meter F1
Dressilk											
Number (n)	15	15	15	15	15	15	15	15	15	15	15
Mean	53.40	93.60	87.07	110.53	482.63	0.19	26.69	27.73	0.66	0.62	0.06
Median	58.00	91.00	65.00	90.00	516.50	0.19	26.40	28.00	0.43	0.72	0.05
Std. deviation	27.66	23.14	54.17	58.50	81.00	0.12	20.42	2.31	0.63	0.33	0.05
Minimum	0.00	52.00	29.00	26.00	325.00	0.04	2.84	23.00	0.05	0.06	0.00
Maximum	90.00	153.00	191.00	241.50	575.50	0.55	67.10	30.00	1.89	0.94	0.20
Untreated skin											
Number (n)	15	15	15	15	15	15	15	15	15	15	15
Mean	57.00	86.13	65.60	194.63	414.40	0.17	19.94	24.67	0.64	0.72	0.09
Median	51.00	88.00	45.00	130.50	411.00	0.15	15.60	26.00	0.53	0.78	0.07
Std. Deviation	17.84	10.56	67.84	261.24	79.12	0.13	17.68	5.64	0.64	0.29	0.06
Minimum	25.00	69.00	16.00	17.50	320.00	0.05	1.38	13.00	0.05	0.09	0.01
Maximum	83.00	106.00	253.00	1105.00	562.50	0.48	57.80	30.00	2.22	0.97	0.20
Biobrane											
Number (n)	15	15	15	15	15	15	15	15	15	15	14
Mean	59.33	98.20	126.80	134.40	501.87	0.18	29.45	23.80	0.88	0.53	0.07
Median	64.00	99.00	123.00	138.50	482.00	0.14	23.00	24.00	0.52	0.69	0.07
Std. deviation	22.84	13.49	83.11	60.15	88.21	0.09	21.74	4.65	0.76	0.34	0.04
Minimum	4.00	78.00	16.00	41.00	394.50	0.09	0.64	14.00	0.04	0.07	0.00
Maximum	98.00	127.00	331.00	232.00	699.00	0.42	79.70	30.00	2.02	0.97	0.13

Table 5 – Results of the objective scar evaluation of the hand after 6 months.

Objective scar evaluation of the face after 6 months	O2C SO2	O2C Hb	O2C Flow	Mexa-meter Mean Melanin	Mexa-meter Mean Erythem	Tewa-meter Stand-ard AW	Tewa-meter TEWL	Tewa-meter Mean	Cuto-meter R 0	Cuto-meter R 2	Cuto-meter F1
Dressilk											
Number (n)	15	15	15	15	15	15	15	15	15	15	15
Mean	54.53	88.80	142.67	126.87	555.07	0.25	11.16	24.47	1.10	0.64	0.15
Median	59.00	90.00	134.00	129.00	552.50	0.17	10.20	26.00	0.84	0.79	0.10
Std. deviation	20.49	23.47	54.75	28.69	76.15	0.23	8.32	5.49	0.74	0.33	0.10
Minimum	14.00	12.00	29.00	76.50	387.00	0.07	2.43	10.00	0.22	0.10	0.02
Maximum	83.00	116.00	234.00	196.50	695.50	0.90	23.20	30.00	2.63	0.98	0.37
Untreated skin											
Number (n)	15	15	15	15	15	15	15	15	15	15	15
Mean	52.13	92.60	126.67	123.17	516.70	0.11	8.84	24.80	1.09	0.69	0.13
Median	57.00	94.00	123.00	120.50	527.50	0.10	7.30	26.00	0.88	0.86	0.11
Std. deviation	21.94	12.51	76.98	43.70	119.31	0.03	7.21	3.51	0.72	0.37	0.08
Minimum	1.00	66.00	32.00	35.00	273.00	0.04	0.75	20.00	0.25	0.08	0.05
Maximum	83.00	115.00	265.00	178.00	712.50	0.17	24.40	30.00	2.50	1.00	0.28
Biobrane											
Number (n)	15	15	15	15	15	15	15	15	15	15	15
Mean	61.67	97.07	195.73	123.30	540.63	0.14	11.93	25.60	0.97	0.78	0.20
Median	64.00	97.00	155.00	117.00	587.50	0.13	10.90	27.00	0.64	0.92	0.08
Std. deviation	22.57	12.70	98.76	29.42	106.25	0.08	9.74	3.89	0.66	0.35	0.28
Minimum	0.00	64.00	27.00	87.00	263.50	0.04	1.82	18.00	0.25	0.10	0.03
Maximum	99.00	113.00	367.00	185.50	641.50	0.36	31.80	30.00	2.22	1.23	1.01

Table 6 – Mexameter evaluation of the erythem level of the hand after 6 months, significant differences between the treated and untreated skin could be detected (p=0.015).

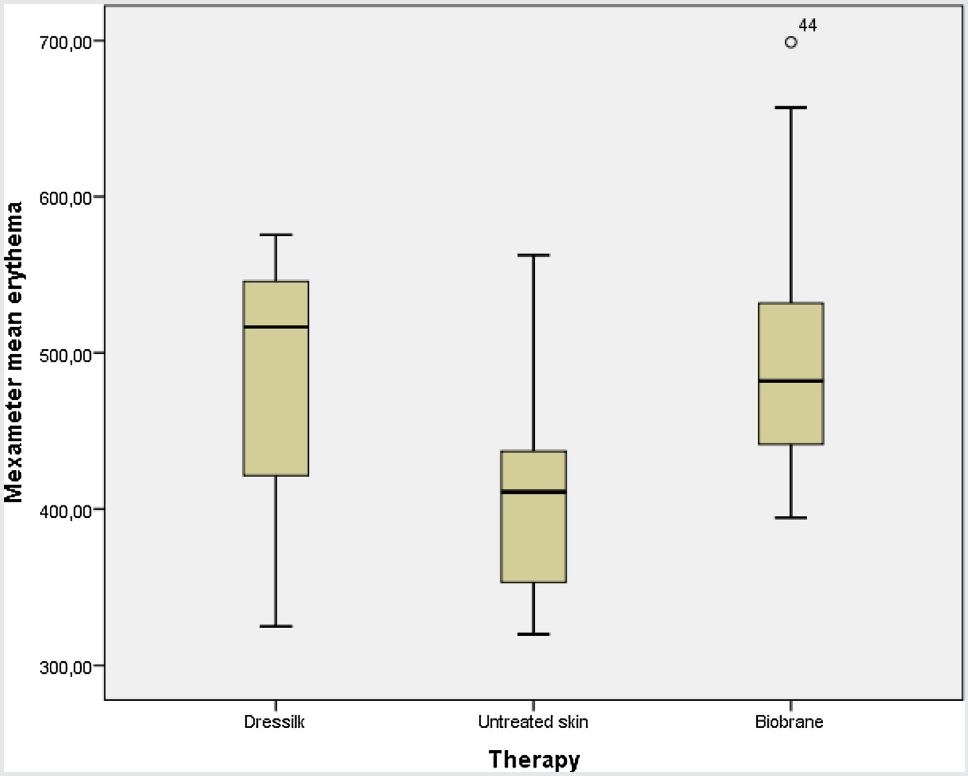

Table 7 – Tewameter evaluation of the hand after 6 months, significant differences between Biobrane and Dressilk could be detected (p=0.048).

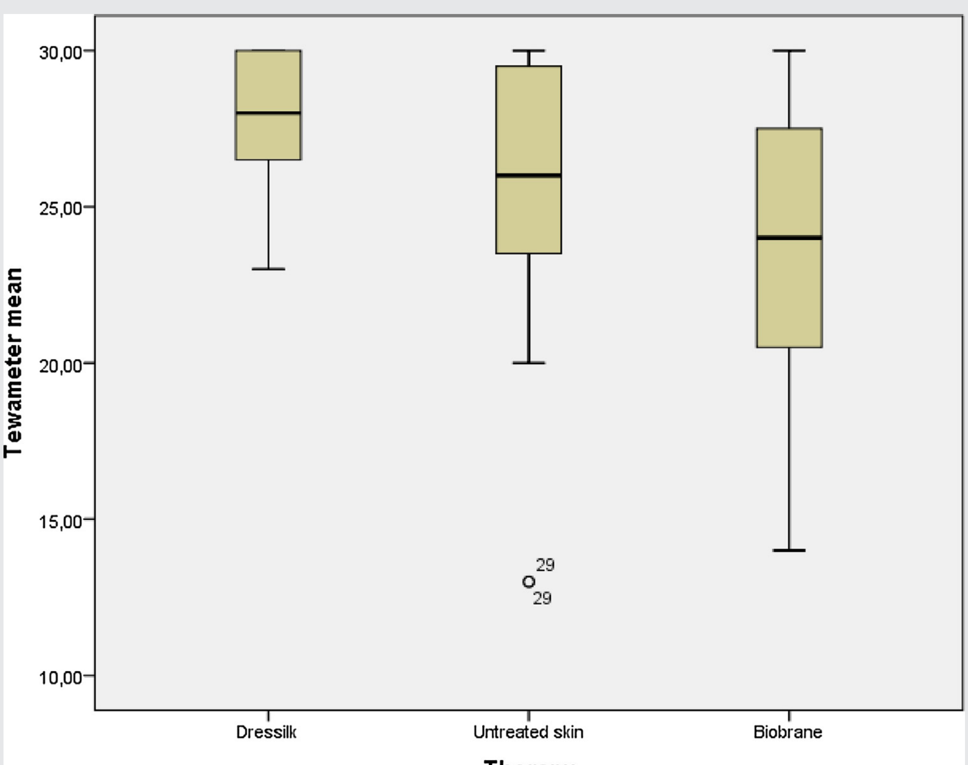

Table 8 – Results of the objective scar evaluation of the hand (n = 15) and the face (n = 15) after 12 months. Pairwise comparison between Dressilk, Biobrane and untreated skin. Overall p value based on Friedman's test for the three groups, pairwise comparison based on Wilcoxon rank sum test for paired data (statistical significant data marked).No statistical significant differences.

	Overall (p Values of Friedman's Test)	Biobrane/Dressilk (Wilcoxon test)	Biobrane/untreated skin (Wilcoxon test)	Dressilk/untreated skin (Wilcoxon test)
Hand				
O2C SO2	0.510	–	–	–
O2C rHb	0.320	–	–	–
O2C flow	0.404	–	–	–
Mexamater melanin	0.853	–	–	–
Mexameter erythem	0.152	–	–	–
Tewameter standard AW	0.373	–	–	–
Tewameter TEWL	0.765	–	–	–
Tewameter mean	0.864	–	–	–
Cutometer R0	0.570	–	–	–
Cutometer R2	0.728	–	–	–
Cutometer F1	0.117	–	–	–
Face				
O2C SO2	0.797	–	–	–
O2C rHb	0.182	–	–	–
O2C Flow	0.654	–	–	–
Mexamater melanin	0.674	–	–	–
Mexameter erythem	0.571	–	–	–
Tewameter standard AW	0.037	0.056	0.153	0.585
Tewameter TEWL	0.840	–	–	–
Tewameter mean	0.643	–	–	–
Cutometer R0	0.132	–	–	–
Cutometer R2	0.563	–	–	–
Cutometer F1	0.394	–	–	–

based on the reflection and absorption of light [22] and through a special mechanism able to show differences in erythema or pigmentation. Strong pigmented scars are conspicuous and often concern the patient [42]. Bond et al. showed that redness of normal scars fades approximately 7 months after incisional or excisional wounding [42] whereas Danielsen et al. proofed erythema to persist longer than one year in split thickness skin graft donor sites [41]. Interestingly Bond used subjective evaluation tools solely through reviewing photographs through different observers. In contrast to this Danielsen objectively measured erythema and pigmentation with a DermaSpectrometer®. Congruently with Bond and Danielsen the subjective scar evaluation of the hand after 6 months showed no subjective significant differences in pigmentation, whereas the objective Mexameter® measurements did reveal significant differences. Nevertheless subjectively not detectable differences in pigmentation after only 6 months suggest a fast wound healing and scar maturation after treatment with Biobrane® or Dressilk®.

Skin elasticity measurements with the Cutometer® are proved to be highly reliable and reproducible for burn scars [22–25]. In the current study Cutometer® measurements as well as the subjective scar evaluation with the VSS and the POSAS after 6 and 12 months did not reveal any significant differences between the treated and untreated areas. Rennekampff et al. compared split thickness skin graft donor sites 6 months after treatment with different wound dressings to uninjured skin and found almost normal values for viscoelastic measurements with the Cutometer® [46]. Underlining our findings, their study no significant differences between the two different wound dressings regarding elasticity could be detected. Interestingly different studies evaluating skin elasticity with the Cutometer® in a 6–24 months follow-up after treatment of superficial partial thickness burns revealed less pliability compared to normal skin [8,43,44]. Anthonissen performed Cutometer® measurements of burn scars after conservative treatment or grafting and found scars never reaching the elasticity of normal skin [25]. Hereby it should be underlined, that the initial burn depth highly influences the scarring. Vloemans found for instance that skin elasticity measured by Cutometer®, 1year after treatment of partial thickness wounds with hydrocolloid-derived dressing or glycerol preserved allograft skin similar to normal skin [45]. These findings can be underlined by our data.

Trans epidermal water loss is an indicator of softness and hydration of the skin [23] and the most important physiological characteristic to evaluate the skin barrier function [25,30]. It is caused by destruction of the lipoprotein complex in the stratum corneum of the skin [26,30]. The TEWL measurements six months after injury and treatment with Biobrane® and Dressilk® revealed normal skin levels. This indicates a sufficient treatment with both wound dressings. It is known, that TEWL is high in hypertrophic scars [47] as well as burn wounds [26]. During the healing of superficial partial thickness burns there is a significant correlation between mean TEWL and time after burn as the TEWL usually approaches the level of normal skin between 6 and 13 months after injury [25,30,41]. This way scar maturation after burn can be evaluated through the TEWL. However, the ability to normalize the barrier function of the stratum corneum depends on the initial burn wound depth [30]. Interestingly hand burns treated with Dressilk® showed slightly higher values for TEWL after 6 months compared to Biobrane®. This phenomenon was not verifiable after 12 months, but suggests, that there might be a slight difference in normalization of the skin barrier function. Overall significant differences could interestingly only be found in the 6-month scar assessment of the hand. This underlines the fast wound healing of the face compared to other peripheral body regions.

After 12 months all detectable differences of the initially burned areas compared to the intact skin vanished showing overall pleasing results for areas treated with Dressilk® and Biobrane®.

5. Conclusion

In the long-term scar assessment after treatment of superficial burns with Biobrane® and Dressilk® both dressings showed pleasing results. After 6 months differences to untreated skin were already scarce. Solely significant differences in color and TEWL could be detected after 6 months. After 12 months these differences could not be verified anymore.

The performed study shows, that Dressilk® is an interesting alternative to Biobrane® for the treatment of superficial burns, especially due to the lower material costs.

Conflict of interest statement

The authors disclose following commercial associations that might create a conflict of interest in connection with the submitted manuscript: This research was supported by Prevor (France). The support included the product itself, costs for personnel (study nurse) and devises used during the wound documentation as well as costs for medical devices used in the follow-up examination and patient's travelling costs for the follow-up examinations. Hereby, Prevor had no influence in the planning and implementation of the study. Furthermore, Prevor had no influence in the data analysis and the submitted manuscript.

Author contributions

All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content and (3) approved the final version to be submitted.

REFERENCES

[1] Lawrence JW, Fauerbach JA, Heinberg L, Doctor M. Visible vs hidden scars and their relation to body esteem. J Burn Care Rehabil 2004;25(January–February (1)):25–32.

[2] Pan BS, Vu AT, Yakuboff KP. Management of the acutely burned hand. J Hand Surg 2015;40(7)1477–84 quiz 1485.

[3] Vloemans AF, Hermans MH, van der Wal MB, Liebregts J, Middelkoop E. Optimal treatment of partial thickness burns in children: a systematic review. Burns 2014;40(March (2)): 177–90.

[4] Wasiak J, Cleland H, Campbell F, Spinks A. Dressings for superficial and partial thickness burns. Cochrane Database Syst Rev 20133: CD002106.

[5] Hermans MH. Results of an internet survey on the treatment of partial thickness burns, full thickness burns, and donor sites. J Burn Care Res 2007;28(November–December (6)):835–47.

[6] Busche MN, Herold C, Schedler A, Knobloch K, Vogt PM, Rennekampff HO. The Biobrane glove in burn wounds of the hand. Evaluation of the functional and aesthetic outcome and comparison of costs with those of conventional wound management. Handchirurgie, Mikrochirurgie, plastische Chirurgie: Organ der Deutschsprachigen Arbeitsgemeinschaft fur Handchirurgie: Organ der Deutschsprachigen Arbeitsgemeinschaft fur Mikrochirurgie der Peripheren Nerven und Gefasse 2009;41(December (6)):348–54.

[7] Mandal A. Paediatric partial-thickness scald burns—is Biobrane the best treatment available? Int Wound J 2007;4 (March (1)):15–9.

[8] Rahmanian-Schwarz A, Beiderwieden A, Willkomm LM, Amr A, Schaller HE, Lotter O. A clinical evaluation of Biobrane((R)) and Suprathel((R)) in acute burns and reconstructive surgery. Burns 2011;37(December (8)):1343–8.

[9] Rogers AD, Adams S, Rode H. The introduction of a protocol for the use of biobrane for facial burns in children. Plast Surg Int 2011;2011:858093.

[10] Greenwood JE, Clausen J, Kavanagh S. Experience with biobrane: uses and caveats for success. Eplasty 2009;9:e25.

[11] Williams N, Stiller K, Greenwood J, Calvert P, Masters M, Kavanagh S. Physical and quality of life outcomes of patients with isolated hand burns—a prospective audit. J Burn Care Res 2012;33(March–April (2)):188–98.

[12] Kanokpanont S, Damrongsakkul S, Ratanavaraporn J, Aramwit P. An innovative bi-layered wound dressing made of silk and gelatin for accelerated wound healing. Int J Pharm 2012;436(October (1–2)):141–53.

[13] Panilaitis B, Altman GH, Chen J, Jin HJ, Karageorgiou V, Kaplan DL. Macrophage responses to silk. Biomaterials 2003;24 (August (18)):3079–85.

[14] Siritientong T, Angspatt A, Ratanavaraporn J, Aramwit P. Clinical potential of a silk sericin-releasing bioactive wound dressing for the treatment of split-thickness skin graft donor sites. Pharm Res 2014;31(January (1)):104–16.

[15] Vasconcelos A, Gomes AC, Cavaco-Paulo A. Novel silk fibroin/ elastin wound dressings. Acta Biomater 2012;8(August (8)):3049–60.

[16] Wharram SE, Zhang X, Kaplan DL, McCarthy SP. Electrospun silk material systems for wound healing. Macromol Biosci 2010;10(March (3)):246–57.

[17] Gil ES, Panilaitis B, Bellas E, Kaplan DL. Functionalized silk biomaterials for wound healing. Adv Healthc Mater 2013;2 (January (1)):206–17.

[18] Sugihara A, Sugiura K, Morita H, et al. Promotive effects of a silk film on epidermal recovery from full-thickness skin wounds. Proc Soc Exp Biol Med 2000;225(October (1)):58–64.

[19] Steinstraesser L, Trust G, Rittig A, et al. Colistin-loaded silk membranes against wound infection with *Pseudomonas aeruginosa*. Plast Reconstr Surg. 2011;127(May (5)):1838–46.

[20] Gil ES, Park SH, Hu X, Cebe P, Kaplan DL. Impact of sterilization on the enzymatic degradation and mechanical properties of silk biomaterials. Macromol Biosci 2014;14(February (2)):257–69.

[21] Schiefer JL, Arens E, Grigutsch D, et al. A prospective intra-individual evaluation of silk compared to Biobrane for the

treatment of superficial burns of the hand and face. Burns 2017;43(May (3)):539–48.
[22] Brusselaers N, Pirayesh A, Hoeksema H, Verbelen J, Blot S, Monstrey S. Burn scar assessment: a systematic review of objective scar assessment tools. Burns 2010;36(December (8)):1157–64.
[23] Lee KC, Dretzke J, Grover L, Logan A, Moiemen N. A systematic review of objective burn scar measurements. Burns Trauma 2016;4:14.
[24] Draaijers LJ, Botman YA, Tempelman FR, Kreis RW, Middelkoop E, van Zuijlen PP. Skin elasticity meter or subjective evaluation in scars: a reliability assessment. Burns 2004;30(March (2)):109–14.
[25] Anthonissen M, Daly D, Fieuws S, et al. Measurement of elasticity and transepidermal water loss rate of burn scars with the Dermalab((R)). Burns 2013;39(May (3)):420–8.
[26] Busche MN, Roettger A, Herold C, Vogt PM, Rennekampff HO. Evaporative water loss in superficial to full thickness burns. Ann Plast Surg 2016(July).
[27] Rankin M, Borah GL. Perceived functional impact of abnormal facial appearance. Plast Reconstr Surg 2003;111(June (7))2140-6 discussion 2147–2148.
[28] Sainsbury DC. Body image and facial burns. Adv Skin Wound Care 2009;22(January (1))39–44 quiz 45-36.
[29] Rnjak J, Wise SG, Mithieux SM, Weiss AS. Severe burn injuries and the role of elastin in the design of dermal substitutes. Tissue Eng Part B Rev 2011;17(April (2)):81–91.
[30] Gardien KL, Baas DC, de Vet HC, Middelkoop E. Transepidermal water loss measured with the Tewameter TM300 in burn scars. Burns 2016(May).
[31] Honardoust D, Varkey M, Marcoux Y, Shankowsky HA, Tredget EE. Reduced decorin, fibromodulin, and transforming growth factor-beta3 in deep dermis leads to hypertrophic scarring. J Burn Care Res 2012;33(March–April (2)):218–27.
[32] Tredget EE, Levi B, Donelan MB. Biology and principles of scar management and burn reconstruction. Surg Clin North Am 2014;94(August (4)):793–815.
[33] Thieme D, Spilker G, Lefering R, Weinand C. O2C laser doppler and digital photo analysis for treatment evaluation of beta-glucan versus provitamin pantothenic acid of facial burns. Facial Plast Surg 2016;32(April (2)):225–31.
[34] Wasiak J, Cleland H. Burns (minor thermal). BMJ Clin Evid 20092009:.
[35] Wasiak J, Cleland H, Campbell F. Dressings for superficial and partial thickness burns. Cochrane Database Syst Rev 2008(4) CD002106.
[36] Balasubramani M, Kumar TR, Babu M. Skin substitutes: a review. Burns 2001;27(August (5)):534–44.
[37] Cassidy C, St Peter SD, Lacey S, et al. Biobrane versus duoderm for the treatment of intermediate thickness burns in children: a prospective, randomized trial. Burns 2005;31(November (7)):890–3.
[38] Atiyeh BS, El-Musa KA, Dham R. Scar quality and physiologic barrier function restoration after moist and moist-exposed dressings of partial-thickness wounds. Dermatol Surg 2003;29 (January (1)):14–20.
[39] Dunkin CS, Pleat JM, Gillespie PH, Tyler MP, Roberts AH, McGrouther DA. Scarring occurs at a critical depth of skin injury: precise measurement in a graduated dermal scratch in human volunteers. Plast Reconstr Surg 2007;119(May (6))1722–32 discussion 1733-1724.
[40] Evers LH, Bhavsar D, Mailander P. The biology of burn injury. Exp Dermatol 2010;19(September (9)):777–83.
[41] Danielsen PL, Jorgensen LN, Jorgensen B, Karlsmark T, Agren MS. Erythema persists longer than one year in split-thickness skin graft donor sites. Acta Derm Venereol 2013;93(May (3)):281–5.
[42] Bond JS, Duncan JA, Mason T, et al. Scar redness in humans: how long does it persist after incisional and excisional wounding? Plast Reconstr Surg 2008;121(February (2)):487–96.
[43] Wisser D, Rennekampff HO, Schaller HE. Skin assessment of burn wounds covered with a collagen based dermal substitute in a 2 year-follow-up. Burns 2004;30(June (4)):399–401.
[44] Rennekampff HO, Rabbels J, Reinhard V, Becker ST, Schaller HE. Comparing the Vancouver Scar Scale with the cutometer in the assessment of donor site wounds treated with various dressings in a randomized trial. J Burn Care Res 2006;27(May–June (3)):345–51.
[45] Vloemans AF, Soesman AM, Suijker M, Kreis RW, Middelkoop E. A randomised clinical trial comparing a hydrocolloid-derived dressing and glycerol preserved allograft skin in the management of partial thickness burns. Burns 2003;29 (November (7)):702–10.
[46] Rennekampff HO, Rabbels J, Pfau M, Schaller HE. Evaluating scar development with objective computer-assisted viscoelastic measurement. Kongressband/Deutsche Gesellschaft fur Chirurgie. Deutsche Gesellschaft fur Chirurgie. Kongress 2002;119:749–55.
[47] Hayashida K, Akita S. Quality of pediatric second-degree burn wound scars following the application of basic fibroblast growth factor: results of a randomized, controlled pilot study. Ostomy Wound Manage 2012;58(August (8)):32–6.