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

A R T I C L E  I N F O

Article history:
Accepted 28 July 2017

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

A B S T R A C T

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.

© 2017 Elsevier Ltd and ISBI. All rights reserved.

* 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/© 2017 Elsevier Ltd and ISBI. All rights reserved.
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 proved 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 20min. 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 x 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/m²).

![Fig. 1](image)

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

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).

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

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

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).

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

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 R0 | Cuto-meter R2 | Cuto-meter F1 |
|-----------------------------------------------------|---------|--------|----------|-------------------------|---------------|---------|------------------------|----------------|-------------|-------------|-------------|-------------|-------------|
| Dressilk                                            |         |        |          |                         |               |         |                        |                |             |             |             |             |             |
| Number (n)                                          | 15      | 15     | 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         | 0.05        |
| 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           | 15           | 15          |
| Mean                                                | 57.00   | 86.13  | 65.60    | 194.63                  | 434.40        | 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           | 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

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

### 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.

<table>
<thead>
<tr>
<th></th>
<th>Overall (p Values of Friedman’s Test)</th>
<th>Biobrane/Dressilk (Wilcoxon test)</th>
<th>Biobrane/untreated skin (Wilcoxon test)</th>
<th>Dressilk/untreated skin (Wilcoxon test)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2C SO2</td>
<td>0.510</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>O2C Hb</td>
<td>0.320</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>O2C flow</td>
<td>0.404</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mexameter melanin</td>
<td>0.853</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mexameter erythema</td>
<td>0.152</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Tewameter standard AW</td>
<td>0.373</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Tewameter TEWL</td>
<td>0.765</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Tewameter mean</td>
<td>0.864</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutometer R0</td>
<td>0.570</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutometer R2</td>
<td>0.728</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutometer F1</td>
<td>0.117</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Face</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2C SO2</td>
<td>0.797</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>O2C Hb</td>
<td>0.182</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>O2C flow</td>
<td>0.654</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mexameter melanin</td>
<td>0.674</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mexameter erythema</td>
<td>0.571</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Tewameter standard AW</td>
<td>0.037</td>
<td>0.056</td>
<td>0.153</td>
<td>0.585</td>
</tr>
<tr>
<td>Tewameter TEWL</td>
<td>0.840</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Tewameter mean</td>
<td>0.643</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutometer R0</td>
<td>0.132</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutometer R2</td>
<td>0.563</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutometer F1</td>
<td>0.394</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
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


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


