Available online at www.sciencedirect.com

ScienceDirect

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

A prospective intra-individual evaluation of silk compared to Biobrane for the treatment of superficial burns of the hand and face

Jennifer Lynn Schiefer [a,*], *Elena Arens* [a], *Daniel Grigutsch* [b], *Rebekka Rath* [c], *Alexandra Hoffmann* [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 of Anesthesiology at the University Hospital Bonn, Germany*

[c] *Clinic of General, Thorax and Transplantation Surgery, Katharinenhospital Stuttgart, Germany*

ARTICLE INFO

Article history:
Accepted 8 September 2016

Keywords:
Superficial burns
Silk
Biobrane
Dressilk
Facial burns
Hand burns

ABSTRACT

Introduction: An ever-increasing number of commercially available dressings have been applied to treat superficial burns with the aim to reduce pain and inflammation and lead to a fast wound healing and scar reduction. Nevertheless the search for cheap and effective wound dressing proceeds. Dressilk® consisting of silkworm silk showed good results for wound healing in regards to scarring, biocompatibility and reduction of inflammation and pain. Therefore it seemed to be an interesting product for the treatment of superficial burns.

Methods: In a prospective intra-individual study the healing of superficial burns was evaluated after the treatment with Dressilk® and Biobrane® in 30 patients with burns of the hand and face. During wound healing pain, active bleeding, exudation, dressing change and inflammation were evaluated using the Verbal Rating Scale 1–10. Three months later scar appearance was assessed by VSS (Vancouver Scar Scale) and POSAS (Patient and Observer Scar Scale).

Results: With regard to re-epithelialization, pain, inflammation and acute bleeding both dressings were equivalent. High subjective satisfaction rates were reported for both Dressilk® and Biobrane® dressings in regard to comfort and mobility of the face. Biobrane®, applied as a glove was subjectively preferred for burns of the hand. Regarding their cost efficiency Dressilk® was clearly superior to Biobrane®. Long-term results were similar.

Conclusion: The "ideal" wound dressing maximizes patients' comfort while reducing pain and promoting wound healing. Dressilk® and Biobrane® both provided an effective and safe healing environment, showing low overall complication rates with respect to infection and exudation on superficial burns of the hand and face.

Therefore Dressilk®, being clearly superior to Biobrane® in cost efficiency is an interesting alternative especially for the treatment of superficial burns of faces.

* *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.2016.09.005
0305-4179/

1. Introduction

An increasing number of commercially available skin substitutes and biosynthetic dressings can be found for the treatment of superficial burns, which are supposed to support and accelerate wound healing as well as to reduce scarring and optimize the functional outcome [1]. Furthermore patients' comfort including pain reduction, reduced dressing changes and fluid loss are desired [2–7]. Additionally economic aspects are of high priority. Therefore the search for cheap and effective wound dressing proceeds.

In recent years *Biobrane®* (Smith & Nephew, United Kingdom) has become an often applied skin substitute for superficial and partial thickness wounds as it promotes epithelialization and thus leads to a faster wound healing. Biobrane® is a transparent, temporary biosynthetic wound dressing consisting of a nylon mesh, covered with porcine type I collagen which facilitates the re-epithelization of wounds [8–10]. The handling of Biobrane® is uncomplicated, after wound debridement it is applied and does not require additional dressing changes. Instead it detaches spontaneously during re-epithelialization of the wound [1,8,11].

Since thousands of years *silk* spun by the silkworm has been used to produce textiles. In the last years silks have been in the focus of research due to their extraordinary mechanical and biochemical properties [12]. Silkworm silk consisting of the protein fibroin showed good results for wound healing in regards to scarring, biocompatibility and reduction of inflammation and pain. Once applied on the wound bed, the silk adheres, becomes dry and peels off by itself when the re-epithelialization of the wound is completed [11]. Biocompatibility of silk was evaluated in many studies and it could be shown, that it is not toxic and does not lead to skin irritation and sensitization [12–15]. Additionally we have evaluated the healing of skin graft donor sites after treatment with *Dressilk®* (PREVOR, France) which consists of silkworm silk compared to Biobrane® and Polymem® in a former study [11]. Hereby the handling of Dressilk® was similar to Biobrane®. Furthermore wound healing, exudation and pain were similar to Biobrane [11]. Therefore Dressilk® (Fig. 1) made out of silkworm silk seemed to be an interesting product for the treatment of superficial burns.

Fig. 1 – Dressilk® before application.

2. Material and methods

The present study evaluated the wound healing 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 partial thickness burns of the hand or face were treated with Biobrane® and Dressilk® in an intra-individual study design (Tables 1 and 2). Burn depth was clinically assessed by admission through a senior burn specialist using standard clinical characteristics (skin color, capillary refill, skin pliability, sensation, presence of blisters and the presence of thrombosed vessels). After inclusion in the study, the burned wound was debrided and cleaned according to our (standard of care) SOC. Then half of the burned area received an application of Biobrane®, while the other half was treated with Dressilk®. All wounds were assessed and treated following SOC of the Cologne-Merheim Burn Center in further course (Fig. 2).

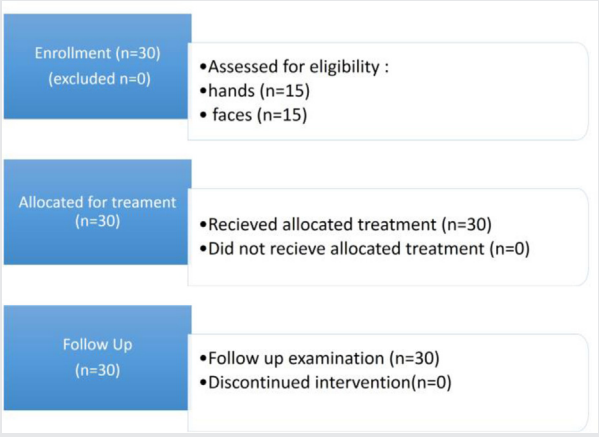
2.1. *Patients*

After admission, each patient with partial thickness burns of the hand or face requiring debridement and fulfilling the inclusion criteria was offered a participation in the study with dressing simultaneous application of Biobrane® and Dressilk®. Inclusion criteria were as follows: (a) participants of both genders must be at least 18 years old and in a good physical condition (b) a superficial partial thickness burn of the hand or face caused by fire/flame or contact must exist (c) the burn wound requires debridement and would usually receive a dressing after debridement, (d) the patient's consent for treatment with Biobrane® and Dressilk® simultaneously and participation in the follow-up examinations has been received (e) the wound area is ≥0,5% total burned surface area (TBSA). Exclusion criteria were listed as (a) lack of consent and compliance to participate in the study and the required follow-up examinations, (b) pregnancy or nursing, (c) history of allergy and/or known sensitivity to porcine collagen or silk, (d) skin injuries caused by a long term therapy with cortisone, (e) dysfunction of blood clotting, (f) patients with electrical or chemical burns, (g) pre-enrolment dressings with Flammacerium or silver nitrate. During the period between April 2015 and November 2015 30 patients met the criteria and were enrolled (Table 1).

2.2. *Wound evaluation*

Additionally wound healing was evaluated on days 2, 4, 8, 12, 16, 24, 48 and after 3 months and documented by the principal investigator during the study in a standardized case report form in regards to (1) pain, (2) exudation, (3) inflammation, (4)

Table 1 – Patient enrollment, treatment and follow-up examination.



dressing change, (5) time to complete wound closure in days and (6) complications. Results were expressed using the Verbal Rating Scale 1–10 (VRS) (1 = no event, 10 = maximum expression of event). Additionally all wounds were documented by standardized digital photography imaging. Evaluation of active bleeding, exuding and inflammation of the wound was done during wound inspection. At the beginning gauze was applied above the dressings. As soon as exudation declined, we did not apply anything on top of the dressings. In case of any sign of inflammation, the dressings were completely removed and the wound was cleaned with Prontosan® solution and conventional treatment conducted.

After hospital discharge regular consultations followed, until final wounds closure (defined as closure of more than 95% of the total wound area) was confirmed.

2.3. *Scar evaluation*

A follow up examination was performed three months after treatment. All study areas were documented by standardized digital photographic imaging and the scars assessed with the Vancouver Scar Scale (VSS) and the Patient and Observer Scar Assessment Scale (POSAS®). The traditional VSS is a validated subjective scale for scar assessment [16–19]. Additionally the POSAS was used, which is one of the only scar assessment tools that includes a scar evaluation of patients and physicians. Due to this the POSAS is proven to be feasible, effective, reliable, and valid in many studies [20]. Therefore it is currently considered to be one of the most suitable scar assessment scales [19–23]. During the follow up examination after three months at first two observers filled out the observer part of the POSAS and VSS individually. Afterwards the patients completed their part of the POSAS. In order to prevent inter-observer errors the same two investigators assessed all scars during the whole study.

2.4. *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. The alpha mistake was set to 0.05 with a power of 80%. Thus a difference of 1.5 standard derivations can be calculated statistically with 20 patients. Due to this and to allow dropouts without compromising statistics altogether 30 patients were included in the study. Statistical significance was accepted at p-values <0.05. The Friedman and Wilcoxon test were performed to identify statistical significant differences between the subgroups.

3. Results

Altogether 30 patients were included in the study. All patients completed the trial and took part at the follow up examination after 3 months. Therefore we assessed no dropouts and data was found to be complete for all enrolled patients. 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 (Table 1).

Within the study period of 48 days all wounds were healed (Table 2). We could not record complicated or prolonged healing for any patient or dressing type. In all cases we detected full re-epitheliazation and a stable scar.

Costs for Biobrane® were approximately ten times higher than for Dressilk® in our clinic.

3.1. *Pain, acute bleeding, exudation, inflammation and adverse events*

Concerning the pain levels no significant differences could be found for both used dressings during the first 16 days of treatment. The highest pain level was day 1 (VRS: Biobrane® 2.87 ± 1.41 Dressilk® 3.3 ± 1.8 of 10, p=0.157) followed by day 2 (VRS: Biobrane® 2 ± 1.1, Dressilk® 2.57 ± 1.94 of 10, p=0.102). During the course of the wound healing pain declined in all cases regardless of the used dressing with the least amount of pain at postoperative day 16 (VRS: Biobrane® 1, Dressilk® 1 of 10, p=1). Hereby a slightly higher pain level was detected for Dressilk® (Table 3) though the only statistical difference could be found on day 4 (p=0.048).

Furthermore a difference in pain level could be found in depending on the injured body region. Pain levels of the face were lower than on the hand, regardless of the applied dressing with a VRS on day 1 with 2.9 (Biobrane®) and 3.9 (Dressilk®) p=0.157 for the hand and 2.8 (Biobrane® and Dressilk®) p=1 for the face. Hereby the pain levels for the face showed no difference in regards to the applied dressing. Pain levels of the hand were slightly higher (Table 3) but not significant after application of Dessilk® compared to Biobrane® (day 1: p=0.157; day 2: p=0.102; day 4: p=0.066; day 8: p=0.269; day 12: p=0.276; day 16: p=1; day 24; p=1).

Acute bleeding was not detected in any patients in the first 16 days during wound healing concerning the areas treated with Biobrane® and Dressilk®.

Dressilk® was slightly superior to Biobrane® in wound exudation. The maximum level of exuding could be found at

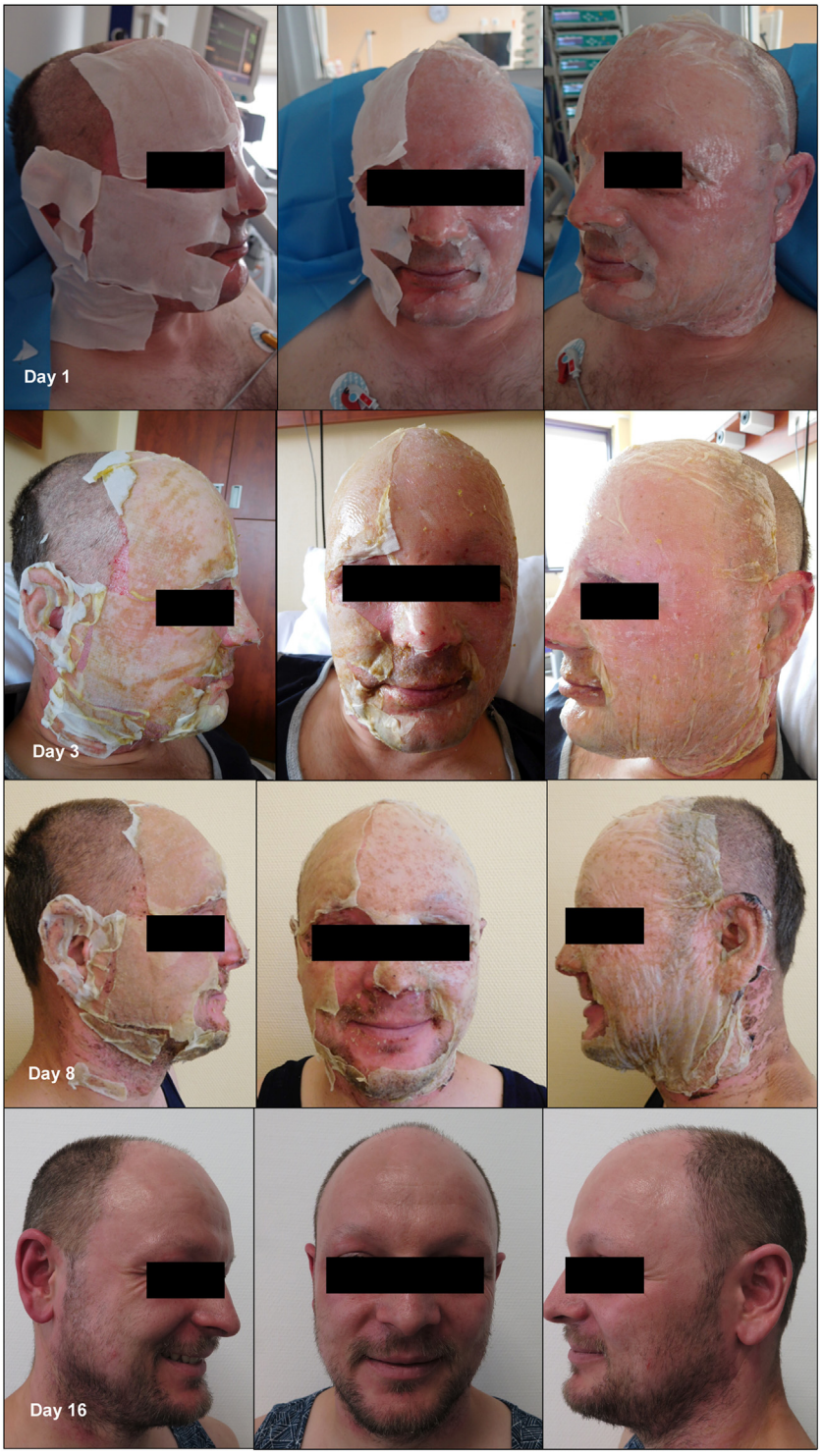


Fig. 2 – Patient with a burn in the face treated with Biobrane® and Dressilk® (photos taken on the day of injury, during the healing and after 1 month).

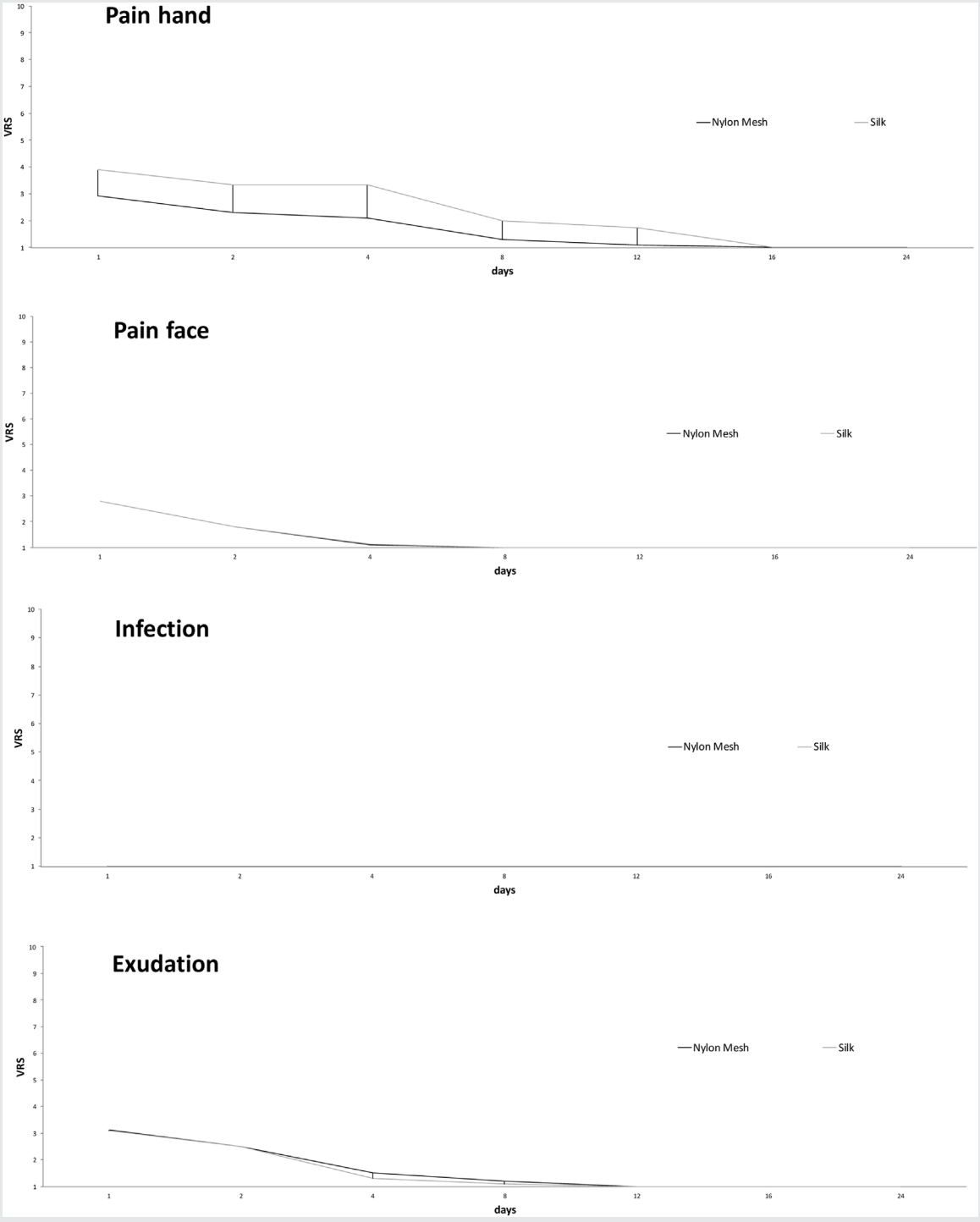
postoperative day 1 for both dressings (VRS: Dressilk® and Biobrane® 3.1 of 10, p=1). In the following days we noticed a rapid decrease of exudation rates for both dressings. On day 4 most of the wounds were left open and exudation could only be detected in a few cases (VRS: Biobrane® 1.5, Dressilk® 1.3 of 10, p=0.059). Significant differences between the two dressings could not be detected (day 1: p=1; day 2: p=0.655; day 4: p=0.059; day 8: p=0.257; day 12: p=1; day 16: p=1; day 24: p=1).

Regarding the aspect of inflammation rates signs of infection (i.e., swelling and redness) were not recorded in any of the 30 patients.

Table 2 – Overview of the treated patients, their age, gender, location of injury, total burned body surface area, time until 95% wound closure in days, time until removal of Biobrane® and Dressilk® and information regarding nicotine consummation.

Patient number	Age in years	Gender	Treated body region	Burned surface area hand/face in %	Total burned surface area in % of the total body surface	Smoker	Complications	Days until removment of silk	Days until removement of Biobrane	Days until wound closure of >95%
1	31	m	Face	2,00	31,00	Yes	No	13	13	17
2	45	m	Face	2,00	12,00	Yes	No	10	10	10
3	36	m	Face	1,00	1,00	Yes	No	8	8	8
4	19	m	Face	1,00	8,50	No	No	8	8	8
5	46	m	Face	2,00	12,50	No	No	7	7	7
6	39	m	Face	2,00	6,50	No	No	13	13	13
7	35	m	Face	1,50	4,50	Yes	No	7	7	7
8	30	m	Face	2,00	3,00	No	No	11	11	11
9	37	m	Face	1,00	4,75	Yes	No	14	14	14
10	48	m	Face	1,50	4,50	No	No	7	8	7
11	44	m	Face	1,50	24,25	No	No	8	8	8
12	44	m	Face	1	16	No	No	5	6	8
13	33	m	Face	2,00	29,50	No	No	9	9	12
14	35	m	Face	2,00	14,00	No	No	12	12	16
15	52	m	Face	1,50	44,5	Yes	No	7	7	7
16	39	m	Hand	1	6,50	No	No	18	18	24
17	41	m	Hand	0.5	0,50	No	No	4	19	19
18	48	m	Hand	0.5	8,50	Yes	No	17	17	19
19	35	m	Hand	0.5	22,00	Yes	No	12	12	15
20	46	m	Hand	0.5	12,50	No	No	13	13	13
21	35	m	Hand	0.5	4,50	Yes	No	10	10	11
22	37	m	Hand	0.5	4,75	Yes	No	14	12	14
23	24	m	Hand	0.8	1,10	Yes	No	13	13	19
24	23	m	Hand	0.5	0,50	No	No	17	17	19
25	33	m	Hand	1	29,50	No	No	12	12	15
26	24	m	Hand	0.5	4,00	No	No	12	12	12
27	35	m	Hand	2,00	14,00	No	No	12	17	22
28	45	m	Hand	1,00	12	Yes	No	18	18	18
29	32	m	Hand	0.5	0,50	No	No	18	18	18
30	45	m	Hand	1,00	12	Yes	No	18,00	18,00	18
Mean				1,50	11,65			12	12	14
SD				0,458831468	10,89284287			4,065696134	4,014485266	4,937424523

Table 3 – Mean values of the VRS during the wound healing from day 1 to 24 regarding "pain of the face, "pain of the hand", "infection" and "exudation" comparing the nylon mesh with silk.



3.2. *Results of subjective scar evaluation*

3.2.1. *VSS and POSAS*

The results of the VSS referring to the *face* presented no significant difference between the areas treated with the different dressings and the untreated areas. The POSAS Patient Scale did not show any statistical differences either. Solely the POSAS Observer Scale showed statistical differences in scar evaluation of the face. Here differences between the treated and non-treated areas could be found regarding pigmentation (Biobrane®-intact skin $p=0.016$ and Dressilk®-intact skin $p=0.016$). Results are shown in detail in Table 4.

Table 4 – Results of the VSS after 3 months comparing the nylon mesh with silk.

	Face				Hand			
	Overall	Biobrane/ Dressilk	Biobrane/ untreated skin	Dressilk/ untreated skin	Overall	Biobrane/ Dressilk	Biobrane/ untreated skin	Dressilk/ untreated skin
VSS								
Pigmentation	0,223	–	–	–	<0.001	0,317	0,002	0,001
Vascularity	0,368	–	–	–	0,009	0,317	0,038	0,041
Pliability	1,000	–	–	–	0,018	1,000	0,066	0,06
Height	1,000	–	–	–	0,05	1,000	0,102	0,102
POSAS Patient Scale								
Pain	1,000	–	–	–	0,18	1,000	0,066	0,066
Itching	0,135	–	–	–	<0.001	1,000	0,011	0,011
Scar	0,050	1.000	0,102	0,102	<0.001	0,317	0,001	0,001
Stiffness	1,000	–	–	–	0,061	–	–	–
Thickness	1,000	–	–	–	0,005	1,000	0,109	0,109
Irregularity	0,135	–	–	–	0,005	0,317	0,017	0,028
Overall	0,050	1.000	0,102	0,102	<0.001	0,157	0,001	0,001
POSAS Observer Scale								
Vascularity_Parameter	0,050	1,000	0,083	0,083	0,05	0,317	0,007	0,007
Vascularity_Category	0,018	1,000	0,059	0,059	0,018	1,000	0,004	0,004
Pigmentation_Parameter	0,002	1,000	0,02	0,02	0,002	1,000	0,001	0,001
Pigmentation_Category	0,001	1,000	0,016	0,016	0,001	1,000	0,001	0,001
Thickness_Parameter	1,000	–	–	–	1	–	–	–
Thickness_Category	1,000	–	–	–	1	–	–	–
Relief_Parameter	0,368	–	–	–	0,368	–	–	–
Relief_Category	0,368	–	–	–	0,368	–	–	–
Pliability_Parameter	1,000	–	–	–	1	–	–	–
Pliability_Category	1,000	–	–	–	1	–	–	–
Surface_Area_Parameter	1,000	–	–	–	1	–	–	–
Surface_Area_Category	0,368	–	–	–	0,368	–	–	–
Overall_Opinion_Parameter	0,018				0,018	–	–	–

Pairwise comparison between Dressilk, Biobrane and untreated skin. Overall p value based on Friedman's test for three groups, pairwise comparison based on Wilcoxon rank sum test for paired data (statistical significant data marked).

In contrast to this, the VSS referring to the *hand* presented significant differences of the treated areas compared to the untreated areas regarding pigmentation (Biobrane®-intact skin p=0.002 and Dressilk®-intact skin p=0.001) and vascularity (Biobrane®-intact skin p=0.038 and Dressilk®-intact skin p=0.041). No significant difference could be found between the applied dressings. In congruence with this, significant differences in scar appearance of the hand could also be found in the POSAS observer and POSAS patient scale. Results are shown in detail in Table 4.

4. Discussion

A fast and unproblematic healing of superficial burns especially for burns on exposed areas like the hand and face is desired and a reduced scarring is important. Especially the facial appearance is often associated with a persons' attractiveness [24,25] and plays an important role in the daily social life.

For a direct comparison between the two evaluated dressings regarding the time to wound closure or pain sensation an intra-individual study seemed most fitting. Furthermore this way differences between individuals like pre-existing illnesses, age, smoking, and individual differences in wound healing or pain sensibility could be eliminated. It is known, that burns in need for frequent dressing changes were found to be extremely painful and distressing for patients and thus require a good pain management [26–28]. Since both dressings remained on the wound after application, painful dressing changes could be prevented. Regardless of this, superficial burns are often painful. Though in this study no difference could be found between the applied dressings regarding dressing changes. Interestingly it has often been shown in literature, that Biobrane® leads to a pain reduction of the burn wound [10,29–31]. In congruence with this burns of the hand treated with Dressilk® showed slightly higher pain levels than hand burns treated with Biobrane, though the results were not significantly different. Furthermore patients described a feeling of stiffness especially on the hand as Dressilk® dried and became stiff through the absorbed wound fluid (Fig. 3). Overall pain levels dropped quickly and mobilization could be begun. Pain reduction and a fast mobilization are especially important for burns of the hand and help to preserve function and prevent impairments [32].

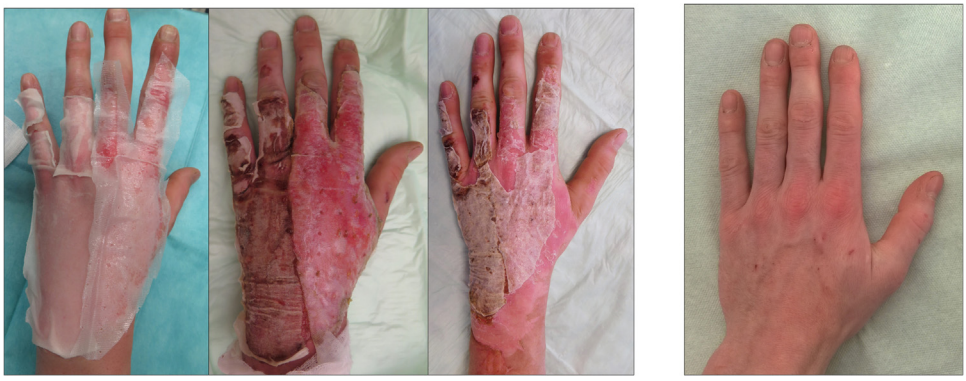


Fig. 3 – Patient with a hand burn treated with Biobrane® and Dressilk® (photos taken on the day of injury, during the healing and after 1 month).

4.1. *Infection*

Furthermore studies have showed, that it may come to small fluid accumulations underneath the nylon mesh that have to be punctured in order to expose the fluid and avoid infection during wound healing [10,33]. They lead to a small number of mild infections in areas treated with Biobrane® [8–11,34–37]. These small fluid accumulations underneath the nylon mesh leading to small local infections could also be detected during our study, although the mesh was punctured and wound fluid was able to drain. Interestingly during our study no infection could be detected in areas treated with Dressilk® since wounds dried quickly. Besides the small fluid accumulations underneath the nylon mesh in a few cases, no further infection could be detected. Different studies had showed that wound infection was reduced through the application of silk [12,13,15,16,38,39]. This phenomenon is also underlined by our data where none of the superficial burn wounds treated with Dressilk® showed an infection. Silk fibers have been an often-used material in biomedical applications, particularly as sutures. During decades of use, silk fibers have additionally proven to be effective in many clinical applications [40–42]. In recent years silkworm silk like in Dressilk®, has become an interesting material for the manufacturing of skin replacement and wound healing products [14,43].

4.2. *Scar assessment*

Patients' satisfaction regarding the esthetic outcome was of high priority. Scarring in visible body regions like the face and hands is normally especially important for the patient [44]. Therefore a subjective scar evaluation was performed after three months with the focus on patient's satisfaction with the VSS and the POSAS.

Interestingly we found reports describing scarring after the application of Biobrane [45,46]. In one case Hassan and Shah described in 2005 a punctuate scarring in a three-year-old after use of Biobrane® for the treatment of a bathtub scald. They described, that immediately after Biobrane® removal 10 days after burn, the punctuate scarring was visible. Furthermore the authors described, that the original perforation patterns of Biobrane® lead to the scarring. In a follow up examination after 10 months the scarring had become soft and pale, but was still present [46]. They concluded, that producing Biobrane® without perforations might prevent similar events [46]. A further case of scarring after the application of Biobrane® was reported by Ahmadi and Williams in 2007 [45]. They described, that a 18 year old man had been treated with Biobrane® after burns through contacts with a barbeque fire. After cleaning of the wound, Biobrane® was applied and cut back over a period of 14 days. After removal the perforation structure seen by Hassan and Shah became visible too. As in the first case, scarring became paler, but in a follow up examination after 2 years they were still apparent [45]. Therefore clinicians must be aware of those seldom, but when visible quite disturbing scars especially while applying Biobrane® on the face or the hands. Despite these reports we found no visible punctual scarring after Biobrane® application. Instead we found a slight difference in appearance of the burned areas of the hands compared to the intact skin. Nevertheless no statistical difference could be found between Biobrane® and Dressilk®. Reports regarding the scarring after application of silk on burn wounds could not be found. Though silk has not been applied on burns as often as Biobrane® has and therefore experiences are sparse [38,47]. Due to this it is possible, that adverse events like allergies or scarring might appear in seldom cases after more frequent application and therefore studies are needed. Interestingly reports could be found in literature showing a scar reduction in tissues though the application of silk [48–50]. Nevertheless these reports did not refer to burn wounds.

5. Conclusion

Due to the fast and unproblematic wound healing of superficial burns on hand and face, silk is an interesting alternative to Biobrane® in this context. Because of the higher pain levels after treatment of hands, it might be especially interesting for the treatment of faces.

Additionally we recommend and have planned a follow up examination with objective scar evaluation tools to investigate the long-term scar development.

Author contributions

All authors have made substantial contributions to atleast one 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.

Conflict of interest

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 devises used in the follow-up examination and patient's traveling 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.

Grant number

None.

REFERENCES

[1] Rahmanian-Schwarz A, Beiderwieden A, Willkomm L-M, Amr A, Schaller H-E, Lotter O. A clinical evaluation of Biobrane(®) and Suprathel(®) in acute burns and reconstructive surgery. Burns 2011;37:1343–8, doi:http://dx.doi.org/10.1016/j.burns.2011.07.010.

[2] Balasubramani M, Kumar TR, Babu M. Skin substitutes: a review. Burns 2001;27:534–44.

[3] Kagan RJ, Peck MD, Ahrenholz DH, Hickerson WL, Holmes 4th J, Korentager R, et al. Surgical management of the burn wound and use of skin substitutes: an expert panel white paper. J Burn Care Res 201334:, doi:http://dx.doi.org/10.1097/bcr.0b013e31827039a6.

[4] Baron H. Textile wound coverings. Langenbecks Arch Klin Chir 1953;274:510–33.

[5] Baron H. Standardization of wound textiles. Nature 1955;175:760–3.

[6] Boateng JS, Matthews KH, Stevens HNE, Eccleston GM. Wound healing dressings and drug delivery systems: a review. J Pharm Sci 2008;97:2892–923, doi:http://dx.doi.org/10.1002/jps.21210.

[7] Agren MS, Werthen M. The extracellular matrix in wound healing: a closer look at therapeutics for chronic wounds. Int J Low Extrem Wounds 20076:, doi:http://dx.doi.org/10.1177/1534734607301394.

[8] Hansbrough JF, Zapata-Sirvent R, Carroll WJ, Dominic WJ, Wang XW, Wakimoto A. Clinical experience with Biobrane biosynthetic dressing in the treatment of partial thickness burns. Burns Incl Therm Inj 1984;10:415–9.

[9] Austin RE, Merchant N, Shahrokhi S, Jeschke MG. A comparison of Biobrane and cadaveric allograft for temporizing the acute burn wound: cost and procedural time. Burns 2015;41:749–53, doi:http://dx.doi.org/10.1016/j.burns.2014.10.003.

[10] Whitaker IS, Prowse S, Potokar TS. A critical evaluation of the use of Biobrane as a biologic skin substitute: a versatile tool for the plastic and reconstructive surgeon. Ann Plast Surg 2008;60:333–7, doi:http://dx.doi.org/10.1097/SAP.0b013e31806bf446.

[11] Schulz A, Depner C, Lefering R, Kricheldorff J, Kastner S, Fuchs PC, et al. A prospective clinical trial comparing Biobrane® Dressilk® and PolyMem® dressings on partial-thickness skin graft donor sites. Burns 2015, doi:http://dx.doi.org/10.1016/j.burns.2014.12.016.

[12] Spiess K, Lammel A, Scheibel T. Recombinant spider silk proteins for applications in biomaterials. Macromol Biosci 2010;10:998–1007, doi:http://dx.doi.org/10.1002/mabi.201000071.

[13] Brown CP, Rosei F, Traversa E, Licoccia S. Spider silk as a load bearing biomaterial: tailoring mechanical properties via structural modifications. Nanoscale 2011;3:870–6, doi:http://dx.doi.org/10.1039/c0nr00752h.

[14] Bhardwaj N, Sow WT, Devi D, Ng KW, Mandal BB, Cho N-J. Silk fibroin-keratin based 3D scaffolds as a dermal substitute for skin tissue engineering. Integr Biol (Camb) 2015;7:53–63, doi:http://dx.doi.org/10.1039/c4ib00208c.

[15] Calamak S, Erdogdu C, Ozalp M, Ulubayram K. Silk fibroin based antibacterial bionanotextiles as wound dressing materials. Mater Sci Eng C Mater Biol Appl 2014;43:11–20, doi:http://dx.doi.org/10.1016/j.msec.2014.07.001.

[16] Nedelec B, Shankowsky HA, Tredget EE. Rating the resolving hypertrophic scar: comparison of the Vancouver Scar Scale and scar volume. J Burn Care Rehabil 2000;21:205–12.

[17] Forbes-Duchart L, Marshall S, Strock A, Cooper JE. Determination of inter-rater reliability in pediatric burn scar assessment using a modified version of the Vancouver Scar Scale. J Burn Care Res 2007;28:460–7, doi:http://dx.doi.org/10.1097/BCR.0b013E318053D3BB.

[18] Rennekampff H-O, Rabbels J, Reinhard V, Becker ST, Schaller H-E. 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;27:345–51, doi:http://dx.doi.org/10.1097/01.BCR.0000216311.61266.00.

[19] Bae SH, Bae YC. Analysis of frequency of use of different scar assessment scales based on the scar condition and treatment method. Arch Plast Surg 2014;41:111–5, doi:http://dx.doi.org/10.5999/aps.2014.41.2.111.

[20] van der Wal MBA, Tuinebreijer WE, Bloemen MCT, Verhaegen PDHM, Middelkoop E, van Zuijlen PPM. Rasch analysis of the Patient and Observer Scar Assessment Scale (POSAS) in burn scars. Qual Life Res 2012;21:13–23, doi:http://dx.doi.org/10.1007/s11136-011-9924-5.

[21] Draaijers LJ, Tempelman FRH, Botman YAM, Tuinebreijer WE, Middelkoop E, Kreis RW, et al. The patient and observer scar assessment scale: a reliable and feasible tool for scar evaluation. Plast Reconstr Surg 2004;113:1960–5 discussion 1966–7.

[22] Truong PT, Lee JC, Soer B, Gaul CA, Olivotto IA. Reliability and validity testing of the Patient and Observer Scar Assessment Scale in evaluating linear scars after breast cancer surgery. Plast Reconstr Surg 2007;119:487–94, doi:http://dx.doi.org/10.1097/01.prs.0000252949.77525.bc.

[23] Deck M, Kopriva D. Patient and observer scar assessment scores favour the late appearance of a transverse cervical incision over a vertical incision in patients undergoing carotid endarterectomy for stroke risk reduction. Can J Surg 2015;58:245–9.

[24] Bick E. The experience of the skin in early object-relations. Int J Psychoanal 1968;49:484–6.

[25] McConnell LK, Lee WW, Black DW, Shriver EM. Beauty is in the eye of the beholder: body dysmorphic disorder in ophthalmic

plastic and reconstructive surgery. Ophthal Plast Reconstr Surg 2015;31:e3–6, doi:http://dx.doi.org/10.1097/IOP.0000000000000019.
[26] Hyland EJ, D'Cruz R, Harvey JG, Moir J, Parkinson C, Holland AJA. An assessment of early Child Life Therapy pain and anxiety management: a prospective randomised controlled trial. Burns 2015, doi:http://dx.doi.org/10.1016/j.burns.2015.05.017.
[27] Upton D, Andrews A. The impact of stress at dressing change in patients with burns: a review of the literature on pain and itching. Wounds 2014;26:77–82.
[28] Fuzaylov G, Kelly TL, Bline C, Dunaev A, Dylewski ML, Driscoll DN. Post-operative pain control for burn reconstructive surgery in a resource-restricted country with subcutaneous infusion of local anesthetics through a soaker catheter to the surgical site: preliminary results. Burns 2015, doi:http://dx.doi.org/10.1016/j.burns.2015.06.003.
[29] 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;858093, doi:http://dx.doi.org/10.1155/2011/858093.
[30] Mandal A. Paediatric partial-thickness scald burns—is Biobrane the best treatment available? Int Wound J 2007;4:15–9, doi:http://dx.doi.org/10.1111/j.1742-481X.2006.00279.x.
[31] Whitaker IS, Worthington S, Jivan S, Phipps A. The use of Biobrane by burn units in the United Kingdom: a national study. Burns 2007;33:1015–20, doi:http://dx.doi.org/10.1016/j.burns.2006.11.017.
[32] Edwards J, Mason S. Hand burn management: minimising pain and trauma at dressing change. Br J Nurs 2013;22(S46):S48–50, doi:http://dx.doi.org/10.12968/bjon.2013.22.Sup20.S46.
[33] Weinzweig J, Gottlieb LJ, Krizek TJ. Toxic shock syndrome associated with use of Biobrane in a scald burn victim. Burns 1994;20:180–1.
[34] Lal S, Barrow RE, Wolf SE, Chinkes DL, Hart DW, Heggers JP, et al. Biobrane improves wound healing in burned children without increased risk of infection. Shock 2000;14:314–8 discussion 318–9.
[35] Tan H, Wasiak J, Paul E, Cleland H. Effective use of Biobrane as a temporary wound dressing prior to definitive split-skin graft in the treatment of severe burn: a retrospective analysis. Burns 2015;41:969–76, doi:http://dx.doi.org/10.1016/j.burns.2014.07.015.
[36] Hubik DJ, Wasiak J, Paul E, Cleland H. Biobrane: a retrospective analysis of outcomes at a specialist adult burns centre. Burns 2011;37:594–600, doi:http://dx.doi.org/10.1016/j.burns.2011.01.006.
[37] Wasiak J, Cleland H, Campbell F, Spinks A. Dressings for superficial and partial thickness burns. Cochrane Database Syst Rev 2013;3, doi:http://dx.doi.org/10.1002/14651858.CD002106.pub4.
[38] Aramwit P, Palapinyo S, Srichana T, Chottanapund S, Muangman P. Silk sericin ameliorates wound healing and its clinical efficacy in burn wounds. Arch Dermatol Res 2013;305:585–94, doi:http://dx.doi.org/10.1007/s00403-013-1371-4.
[39] Pritchard EM, Valentin T, Panilaitis B, Omenetto F, Kaplan DL. Antibiotic-releasing silk biomaterials for infection prevention and treatment. Adv Funct Mater 2013;23:854–61, doi:http://dx.doi.org/10.1002/adfm.201201636.
[40] Postlethwait RW, Dillon ML, Reeves JW. Experimental study of silk suture. Arch Surg 1962;84:698–702.
[41] Kurosaki S, Otsuka H, Kunitomo M, Koyama M, Pawankar R, Matumoto K. Fibroin allergy: IgE mediated hypersensitivity to silk suture materials. Nihon Ika Daigaku Zasshi 1999;66:41–4.
[42] Choudhury AJ, Gogoi D, Chutia J, Kandimalla R, Kalita S, Kotoky J, et al. Controlled antibiotic-releasing *Antheraea assama* silk fibroin suture for infection prevention and fast wound healing. Surgery 2015, doi:http://dx.doi.org/10.1016/j.surg.2015.07.022.
[43] Sheikh FA, Ju HW, Lee JM, Moon BM, Park HJ, Lee OJ, et al. 3D electrospun silk fibroin nanofibers for fabrication of artificial skin. Nanomedicine 2015;11:681–91, doi:http://dx.doi.org/10.1016/j.nano.2014.11.007.
[44] Ren Z, Chang WC, Zhou Q, Wang Y, Wang H, Hu D. Recovery of lost face of burn patients, perceived changes, and coping strategies in the rehabilitation stage. Burns 2015, doi:http://dx.doi.org/10.1016/j.burns.2015.08.033.
[45] Ahmadi H, Williams G. Permanent scarring in a partial thickness scald burn dressed with Biobrane. J Plast Reconstr Aesthet Surg 2009;62:697–8, doi:http://dx.doi.org/10.1016/j.bjps.2008.01.014.
[46] Hassan Z, Shah M. Punctate scarring from use of porous Biobrane. Burns 2006;32:258–60, doi:http://dx.doi.org/10.1016/j.burns.2005.06.013.
[47] Lan Y, Li W, Jiao Y, Guo R, Zhang Y, Xue W, et al. Therapeutic efficacy of antibiotic-loaded gelatin microsphere/silk fibroin scaffolds in infected full-thickness burns. Acta Biomater 2014;10:3167–76, doi:http://dx.doi.org/10.1016/j.actbio.2014.03.029.
[48] Shan Y-H, Peng L-H, Liu X, Chen X, Xiong J, Gao J-Q. Silk fibroin/gelatin electrospun nanofibrous dressing functionalized with astragaloside IV induces healing and anti-scar effects on burn wound. Int J Pharm 2015;479:291–301, doi:http://dx.doi.org/10.1016/j.ijpharm.2014.12.067.
[49] Bellas E, Lo TJ, Fournier EP, Brown JE, Abbott RD, Gil ES, et al. Injectable silk foams for soft tissue regeneration. Adv Healthc Mater 2015;4:452–9, doi:http://dx.doi.org/10.1002/adhm.201400506.
[50] Arasteh S, Kazemnejad S, Khanjani S, Heidari-Vala H, Akhondi MM, Mobini S. Fabrication and characterization of nano-fibrous bilayer composite for skin regeneration application. Methods 2015, doi:http://dx.doi.org/10.1016/j.ymeth.2015.08.017.