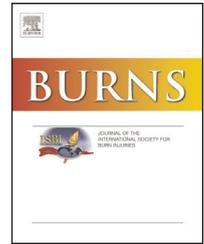


Available online at www.sciencedirect.com

ScienceDirect

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

Superiority of silver-foam over porcine xenograft dressings for treatment of scalds in children: A prospective randomised controlled trial

Matilda Karlsson^{a,b,*}, Moustafa Elmasry^{a,b,c}, Ingrid Steinvall^{a,b},
Folke Sjöberg^{a,b,d}, Pia Olofsson^{a,b}, Johan Thorfinn^{a,b}

^a Department of Hand Surgery, Plastic Surgery and Burns, Linköping University, Linköping, Sweden

^b Department of Clinical and Experimental Medicine, Linköping University, Linköping, Sweden

^c Plastic Surgery Unit, Surgery Department, Suez Canal University, Ismailia, Egypt

^d Department of Anesthesiology and Intensive Care, Linköping University, Linköping, Sweden

ARTICLE INFO

Article history:

Accepted 4 April 2019

Keywords:

Burns

Partial thickness burns

Scalds

Children

Wound dressings

Healing

ABSTRACT

Aim: Our aim was to compare two different regimens for the treatment of children with partial-thickness scalds. These were treated with either a porcine xenograft (EZderm[®], Mölnlycke Health Care, Gothenburg, Sweden) or a silver-foam dressing (Mepilex[®] Ag, Mölnlycke Health Care, Gothenburg, Sweden).

Methods: We organised a prospective randomised clinical trial that included 58 children admitted between May 2015 and May 2018 with partial-thickness scalds to The Burn Centre in Linköping, Sweden. The primary outcome was time to healing. Secondary outcomes were pain, need for operation, wound infection, duration of hospital stay, changes of dressings, and time taken.

Results: The patients treated with silver-foam dressing had a significantly shorter healing time. The median time to 97% healing for this group was 9 (7–23) days compared to 15 (9–29) days in the porcine xenograft group ($p = 0.004$). The median time to complete healing for the silver-foam group was 15 (9–29) days and for the porcine xenograft group 20.5 (11–42) days ($p = 0.010$). Pain, wound infection, duration of hospital stay, and the proportion of operations were similar between the groups. Number of dressing changes and time for dressing changes were lower in the silver-foam dressing group ($p = 0.03$ for both variables).

Conclusions: We compared two different treatments for children with partial-thickness scalds, and the data indicate that wound healing was faster, fewer dressing changes were needed, and dressing times were shorter in the silver-foam group.

© 2019 Elsevier Ltd and ISBI. All rights reserved.

1. Introduction

Scalds are the most common type of burns in children in Europe [1], and at the Linköping Burn Centre, Sweden, they

make up 70% of all burns in children under the age of 2 years. Scalds typically cause partial-thickness injuries, covering a relatively small percentage of the child's body.

They usually affect the superficial parts of the skin and damage both the epidermal and dermal layers, but leave the

* Corresponding author at: The Burn Centre, Linköping University Hospital, 58185, Linköping, Sweden
E-mail address: Matilda.Karlsson@regionostergotland.se (M. Karlsson).

<https://doi.org/10.1016/j.burns.2019.04.004>

0305-4179/© 2019 Elsevier Ltd and ISBI. All rights reserved.

deeper tissues intact. Healing of a superficial scald normally occurs within two to three weeks of injury. Longer healing times and wound infections are associated with an increased risk of scarring, which indicates the importance of preventing infections during healing [2–5].

We use the type of dressing for these burns that we think provide the optimal conditions for re-epithelialisation of the wound. Our choice also depends on to what extent the dressing is adjustable for different sites, as well as how easy it is to use, and how cost-effective [6]. For scalds, porcine xenografts pre-meshed 1:1 have been our standard since 2013 (EZderm[®], Mölnlycke Health Care, Gothenburg). They have several benefits in that they are reported to reduce infections and pain, and undergo fewer changes of dressing, as well as preventing the loss of heat and fluid, all of which leads to potentially better re-epithelialisation [7–12]. Another of their beneficial characteristics is that they tend not to adhere to burns that are deep or infected, or both, which in some instances are used for diagnostic guidance.

However, they also have drawbacks. Studies have reported less satisfactory scarring with xenografts in partial thickness wounds, possibly caused by a more pronounced immune response to the biological compounds of the dressing [13–16]. In addition, the use of animals as donors raises questions about transmission of viruses and diseases [17,18]. Lastly, there are the cultural and ethical aspects of using pigs as donors [19]. Religious leaders within Hinduism, Buddhism, Islam, Sikhism, and Jehovah's Witnesses raise concerns about products derived from pigskin when there are other options [20,21].

A synthetic dressing, such as Mepilex Ag[®] (Mölnlycke Health Care, Gothenburg, Sweden), which is a foam dressing containing silver, can serve as an alternative to a porcine xenograft, as it combines the advantage of needing fewer changes of dressing with that of an antimicrobial substance that reduces the bacterial burden in the wound [22].

Our aim in this study was to compare the clinical outcomes of porcine xenograft and silver-foam dressings for the treatment of partial-thickness scalds in children. The primary outcome was the time to complete healing. The secondary outcomes were pain, wound infection, duration of hospital stay, need for operation, number of changes of dressing, and time taken.

2. Patients and methods

This prospective randomised clinical trial was approved by the regional ethics review board in Linköping, Sweden (No. 2014/364-31 and 2016/77-32) and is registered at [ClinicalTrials.gov](https://www.clinicaltrials.gov) PRS.

Children aged 6 months to 6 years with partial-thickness scalds who were admitted within 72 h of injury and with burns suitable for dressing with a porcine xenograft (as judged by the burn surgeon on duty) were eligible and enrolled after parents or guardians had given their consent to participation. Children with only epidermal, or with full-thickness, burns were excluded, as were those with burns on non-approved areas (palms, soles, or face) alone, suspected wound infection (where it would be likely that porcine xenograft would not adhere), severe coexisting cutaneous trauma, skin disease, and children with a known hypersensitivity to silver.

The presence of a partial thickness burn was judged clinically on admission by an experienced burn surgeon who examined colour, pain sensation, and capillary refill, and noted the extent and the depth of the burn using the Lund and Browder chart [23]. After initial debridement of the wound under sedation the scalded area was photographed. The depth of the burn was recorded as either “superficial” or “deep” dermal burn. The extent of the burn was documented as the percentage of the total body surface area (TBSA %) that was burned. If the scald was suitable for a porcine xenograft a coded envelope containing the random assignment for the dressing was opened. Coded envelopes were created externally before the study started and opened when the guardian's consent had been given. Guardians were told after the first application what kind of dressing their child had been given.

All children were thoroughly washed with saline at all dressing changes before taking swabs on 1 cm² of the burned skin to assess microbial growth according to the Levine method [24] followed by application of the study dressing under clean conditions. Samples of capillary C-reactive protein (CRP) were collected at all study visits and analysed at the bedside using the instrument “QuickRead go”[®] (Orion Diagnostica Oy).

The silver-foam dressing was cut to fit the wound and held in place with a crepe bandage, and an elasticated tubular bandage or age-adapted elasticated cotton garments, or both.

The porcine xenograft was cut to fit and applied to the wound, fixed outside the wound edges with a liquid topical skin adhesive (Dermabond[®] Mini, Ethicon LLC, Puerto Rico, USA) and covered with a layer of nylon sheets (DermaNet[®] DeRoyal, Tennessee, USA) and several layers of AMD Gauze (Kerlix[®], Covidien, Dublin, Ireland). It was held in place in the same way as the silver-foam dressing. According to the standard protocol at the centre no facial dressings were used.

Figs. 1 and 2 show examples of the two study dressings applied in study participants.

Children who were included were treated as both inpatients and outpatients, depending on the extent and depth of the burn. They were followed-up regularly up to three times a week according to our standard protocol for children [25,26]. Guardians with children who had been discharged from hospital were instructed to keep the dressings clean and in



Fig. 1 – Porcine xenograft applied on trunk, 6 days after application.



Fig. 2 – Silver foam dressing applied on trunk.

place until the next visit and to notify the burn centre if the dressing became wet or loose, or if the child developed any new or concerning symptoms.

The silver-foam dressing was changed at each follow-up visit, and the progress of re-epithelialisation of the wound bed was noted. The porcine xenograft remained intact on the surface of the wound until spontaneous separation of the xenograft, whilst the Dermanet[®] and Kerlix[®] were changed at each follow-up visit.

Healing, pain, need for operation, wound infection, duration of hospital stay, dressing time, frequency of dressings, and (local) adverse events were recorded until the wounds had healed completely.

2.1. Healing time

Healing time was calculated from the date of injury to the date when the wound bed was assessed as 97% re-epithelialised and completely (100%) re-epithelialised, with no need for further dressings other than a protective covering to protect against shearing according to both the physician and nurse (definition used in similar studies [5,27–29]). Burn surgeon was asked to state healed % TBSA at all visits and the “actual percentage” was later calculated looking at the initial %TBSA given.

Photographs were taken at all visits until healing was confirmed as complete. No “blinding” was possible because of the characteristics of the porcine xenograft, which adhered to the wound surface until separation. If parts of the burn healed (while others remained open) standard thin polyurethane foam was used to protect the healed area from shearing in both groups. As it has been suggested that the size of the burn may have an impact on the healing time of burns in children [30] we have analysed whether any difference remained between the types of dressing when children with burns of more than 10% and 20% TBSA were excluded.

2.2. Pain

Guardians were instructed on how to rate signs of pain once daily using the Parents' Postoperative Pain Measure (PPPM) [31]. This consists of 15 questions to which the answer YES indicates signs of pain. The maximum score is therefore 15 and

the lowest 0 (which indicates no signs of pain that day) (Supplementary Table 1). Guardians were also asked to report daily if any pain relief was given (if the child was at home). Clinical routine is to use paracetamol as the first choice for pain relief, and opioids if needed. The sedative drugs given before and during dressing changes was not noted, as doses are standardised according to weight, and to the number of doses given previously to that specific child.

Children were also assessed for discomfort or pain before, during, and after dressing changes by the paediatric specialist anaesthesia nurse using the Face, Legs, Activity, Cry, Consolability behavioural pain scale (FLACC) (Supplementary Table 2) [32,33]. The highest score on FLACC is 10, and indicates great stress, pain, or anxiety. Children were sedated during dressing changes with either ketamine or midazolam given intravenously or rectally, though in a few cases propofol and fentanyl were used intravenously, to ensure that the child was comfortable and that adequate wound care could be given. In some cases nitrous oxide or fluorinated isopropyl ether (sevoflurane) was added for optimal sedation.

2.3. Need for operation

The decision to operate on a child was made by the burn surgeon on duty on the day of the visit. Dermal burns that showed no signs of healing within 14–21 days after injury were excised (according to our clinical practice) and either primarily closed or skin grafted, depending on the size and location of the burn. The graft is a split-thickness skin graft harvested from the thigh or buttock. The site of the donor site depends on the extent of the burn as well as the size of graft needed, and is finally decided by the burn surgeon in the operating room. Surgical details were documented.

2.4. Infection of the burn

Wound infections were diagnosed (by the burn surgeon and a consultant physician who specialised in infectious diseases) if they fulfilled at least two of the following criteria based on the American Burn Association definition of burn wound infection [34,35].

- Clinical signs such as localised pain and swelling, spreading erythema, and heat at the affected site.
- Positive bacterial culture growth of the surface wound swab (according to our local guidelines for diagnosis of pathological bacterial growth is a minimum of 10^4 colony-forming units (CFU)/mL).
- Signs of systemic infection indicated by a rise in CRP concentration (reference range <10 mg/L for capillary sampling) together with increased body temperature that exceeded 38°C 48 h after injury where other sources of infection have been excluded.

Data about duration of hospital stay and dressing changes were extracted from the patients' medical records and time for dressing changes from the patient's case report form, noted by nurses as taking less than 10 min, 10–20 min, and so on, for removal of the old dressing and application of the new one.

If any *adverse event* (such as local reaction to the dressing) occurred during the trial, the type of dressing was changed.

3. Statistics

We used STATA (STATA version 15.0, Stata Corp. LP College Station, TX, USA) for the statistical analysis. As the data were judged to be mainly qualitative, and a normal distribution could not be assumed, non-parametric tests were used. To assess the significance of any differences between the two groups we used the Mann Whitney *U* test and the chi squared test or Fisher's exact test (as appropriate). Probabilities of less than 0.05 were accepted as significant. Data are given as median (10th–90th centiles) unless otherwise stated.

4. Results

Fifty-eight children (35 boys and 23 girls) with scalds were enrolled in the study and randomised to treatment with either a porcine xenograft (n = 30) or a silver-foam dressing (n = 28). All children had their study dressing applied within 72 h of injury.

The two treatment groups were comparable in sex distribution, age, weight, previous illnesses, TBSA% burned, and depth of burn (Table 1). Median TBSA for the children was 5 (3–11) %. In the porcine xenograft group 26 of the 30 children (87%) had burns located on the trunk, 15 (50%) on the upper extremity, and 14 (47%) on the lower extremity. In the silver-foam dressing group 25 of the 28 children (89%) had burns on the trunk, 16 (57%) on the upper extremity, and five (18%) on the lower extremity.

None of the participating children were either diagnosed with full thickness burns or died during the study.

4.1. Healing time

The patients treated with silver-foam dressing had a significantly shorter healing time. The median time to 97% healing for this group was 9 (7–23) days compared to 15 (9–29) days in the porcine xenograft group (p = 0.004). The median time to complete healing in the silver-foam group was 15 (7–30) days, and in the porcine xenograft group 20.5 (11–42) days (p = 0.010). When all children with burns of more than 10% TBSA and 20%

TBSA were excluded, the significant differences remained. (For 97% healing and exclusion of TBSA > 10% p = 0.0266, for TBSA > 20% p = 0.0130) For 100% healing and exclusion of TBSA > 10% p = 0.045, for TBSA > 20% p = 0.034).

4.2. Secondary outcomes

Outcomes for pain including the PPPM diary, pain medication, and FLACC scores were similar between groups (Figs. 3–5 and Supplementary Table 3). The PPPM diary was used by 16 in the porcine xenograft group and 14 in the silver-foam group. FLACC scores were all low, and the median scores for all occasions in both groups were zero.

Outcomes for *Need for operation*, *Infection* (and antibiotic use) and *Duration of hospital stay* were similar in the two groups (Table 2).

Four children in the porcine xenograft group underwent operation, as did two in the silver-foam group. Operations were done at six days, 14 days (n = 2), 15 days (n = 2), and 20 days after injury. All six operations received split-thickness skin grafting.

Infection was diagnosed in nine children in the porcine xenograft group and 10 in the silver-foam group. The most common bacteria that was found in swabs from wounds within the first week after injury was *Staphylococcus aureus*, which was found in 86% of all swabs (50/58). Antibiotics were prescribed for 11 children in the porcine xenograft group and 12 in the silver-foam group. The reasons for antibiotic treatment, other than wound infection, were: upper airway infection (n = 1), pneumonia (n = 1), prophylaxis (n = 1), and *group A streptococcus* (n = 1) (clinical routine to treat).

Regarding body temperatures and CRP levels there was no significant difference between groups at any analysed time point (Table 3).

The duration of hospital stay was short in both groups; median time spent in hospital was 2 days for the porcine xenograft group and three in the silver foam group.

The *Number of dressing changes* and time spent by staff on dressing changes were significantly less in children who had silver-foam dressings (p = 0.03 for both variables) (Table 2).

4.3. Exclusion and lost to follow-up

Twelve children were excluded, the most common reasons being that their guardians disapproved of the substance used

Table 1 – Details of the patients by dressing treatment.

	Porcine xenograft (n = 30)	Silver-foam dressing (n = 28)	p value
Sex (M/F)	19/11	16/12	0.630
Age (months):	21 (11–59)	17 (8–35)	0.175
Weight (kg)	13 (9–18)	12 (10–15)	0.326
Previous illnesses	6 ^a	4 ^b	0.732
TBSA%:	5 (3–22)	5 (2–8)	0.450
Superficial dermal	5 (3–13)	5 (2–8)	0.585
Deep dermal	0.5 (0–3)	0 (0–3)	0.089

Data are number, or median (10–90 centiles).

^a Food allergies, croup (cough), asthma and haemangioma.

^b Food allergies, lipoma, club foot, and asthma.

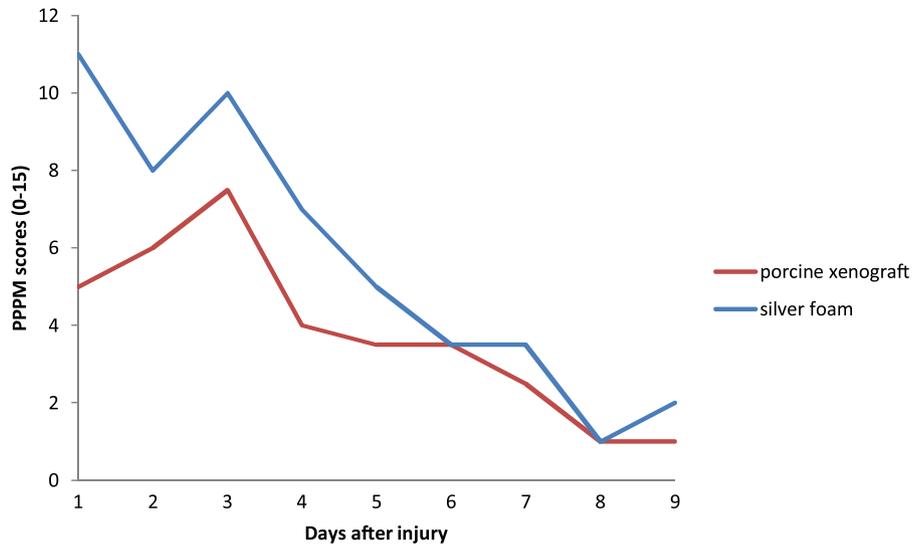


Fig. 3 – Median levels of pain according to the PPPM diary.

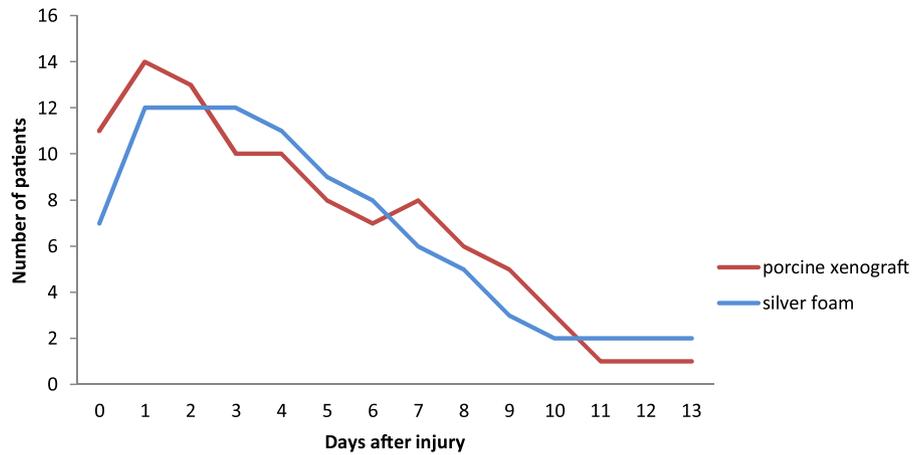


Fig. 4 – Number of patients using paracetamol the first two weeks.

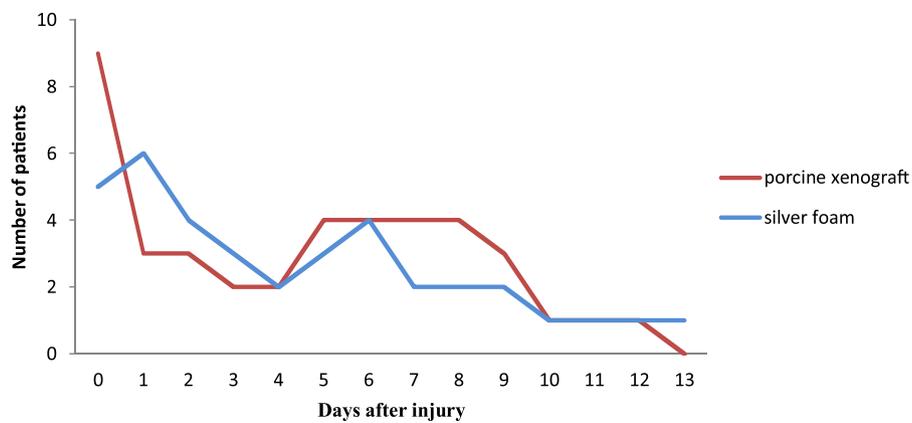


Fig. 5 – Number of patients using opioids the first two weeks.

in the dressings (porcine or silver), or that burns were more than 72 h old at admission, or heavily contaminated meaning that they needed an antibacterial dressing.

All children included were followed up until the wound had healed completely. Two children were referred to another

hospital and the receiving physician was informed of the study so that it could be completed using photographs and scanned copies of the case report form. In one case the child had influenza and could not come to the last follow-up, so the record was finalised using photographs.

Table 2 – Secondary outcomes.

	Porcine xenograft	Silver-foam dressing	p value
Operations	4	2	0.671
Infection	9	10	0.643
Antibiotic use	11	12	0.630
Duration of hospital stay (days)	2 (0-13)	3 (0-8)	0.944
Number of dressing changes	5 (-9)	4 (3-8)	0.031
Dressing time (minutes)	20 (10-50)	20 (10-30)	0.030

Data are number, or median (10-90 centiles).

Table 3 – Details of the body temperature and CRP levels by dressing treatment.

	Porcine xenograft	Silver-foam dressing	p value*
Body temperature			
Day 0-2 (after injury)	37.3 (36.2-38.4)	37.5 (36.8-39.0)	0.423
Day 3-5	37.5 (36.6-39.1)	37.6 (36.4-39.9)	0.960
Day 6-8	37.2 (36.4-38.2)	37 (36.1-37.6)	0.216
CRP levels			
Day 0-2 (after injury)	6.5 (2-66)	5(2-57)	0.825
Day 3-5	12 (2-92)	21.5(2-93)	0.630
Day 6-8	7(2-84)	2(2-83)	0.162
Day 9-11	2(5-23)	2(2-7)	0.078

Data are number, or median (10-90 centiles).
* All p values remained non-significant when using student t-test.

No adverse events happened during the trial.

5. Discussion

This is, to our knowledge, the first prospective, randomised, comparison of porcine xenograft and silver-foam dressings for the treatment of partial-thickness scalds in children.

The silver-foam dressing showed itself to be superior in “time to healing”, and it also reduced the time needed for dressing changes compared with the porcine xenograft. These results are consistent with other studies of silver-foam dressings which have reported similar healing times and shorter healing times with faster and easier dressing changes and less frequent dressing changes than controls [28,36–38].

The clinical importance of the difference in dressing frequency could be discussed. Median number of dressing changes was five in the porcine xenograft group and four in the silver foam group. The clinical routine is to initially change dressing two times a week which probably reflects the minor difference seen between the two groups. As the silver foam dressing can be left in place for up to 7 days a stricter protocol for this study could have been applied. Fewer dressing changes results in less disturbance of the re-epithelialization process and possibly even faster wound closure for the silver foam group.

5.1. Pain

There was no difference in reported pain at any time point. Consistently low pain scores were given on the FLACC before, during, and after dressing changes, which indicated that both dressings had pain-relieving properties. The analgesic effect of both dressings has been reported earlier [36,38]. The low FLACC scores during and after dressing changes probably reflect the effect of the sedation, as we used both sedatives and strong adjuvant analgesics, which resulted in calm and satisfied children [39]. Severe pain and distress has been reported in settings where sedation is not used for dressing changes in children with burns [40,41].

As children were sedated with different methods (the vast majority being rectal sedation though), no conclusions can be drawn regarding pain during dressing change.

Time elapsed after injury results in lower median amounts of PPM and pain medication given (Figs. 1–3), which probably reflects the normal healing course of partial thickness burns, and not the effect of the dressings.

5.2. Wound infection and the effect of silver

There is an ongoing debate among burn centres about the definition of “wound infection”, and we decided that the diagnosis would follow the clinical guidelines described in the Methods section. It was noticeable that there seemed to be no reduction in infection with the use of silver.

The antimicrobial properties of silver have been recognised for a long time even though the mechanism of action is still debated [42]. Silver in its ionised form has broad-spectrum activity against micro-organisms and the silver ions are thought to interact with the cell membrane and disrupt cell replication by binding to bacterial DNA and interfering with the transport of bacterial electrons [43]. In vitro studies have indicated that dressings that contain silver will block bacterial entry from the external environment, retain bacteria in the dressing, and effectively eliminate some of the most common bacteria seen in burns that include *S aureus*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Acinetobacter baumannii*, and *Escherichia coli* [43–47].

We know of little in vivo evidence of the infection-reducing effect of silver, and systematic reviews and Cochrane reports have concluded that dressings that contain silver have not yet been proved to prevent wound infection in safe and un-biased ways [48,49], which is in line with our results. As the use of silver is debated both in hospital and in general, further studies

to compare polyurethane foam with and without silver are required.

It is possible that the fast healing seen in the silver-foam group could potentially be related to other properties of the dressing, such as appropriate control of exudate, and minor stress of the wound bed seen with Safetac[®], a soft type of silicone adhesive in the product. It is said to prevent epidermal loss and pain, and has therefore been suggested for the treatment of partial thickness burns in recent studies in children [28,37].

5.3. Clinical routines for taking care of the children

Our routine is to discharge the children as soon as possible without compromising their safety. Well-adherent dressings with minimal effort by staff are two of the important factors that contribute to our short duration of hospital stay. Rectal sedation is another factor that contributed to early discharge. As is our usual clinical routine, all dressing changes were done by the same small group of experienced and specially-trained nurses. This enabled fast, safe, and effective care of the burned child.

As mentioned earlier the protocol in our burn centre does not apply dressings to fascial burns. However, the use of open treatment with creams/ointments instead is the method of choice. Since a report on permanent mesh patterns in facial burns was published in 2002 our centre does not apply porcine xenograft for this area [50]. Attempts have been made at the centre to apply other dressings in children facial burns, such as foam dressings, with poor results. With the introduction of the age-adapted Tubifast[®] garments vests, tights and gloves (Mölnlycke Health Care, Gothenburg, Sweden) fixation in more difficult areas such as armpits or groins and hands has become easier. Burns to the genitalia according to the protocol in our centre are treated using open treatment strategy, no children in this study was presented with genital burns.

One aspect that we have not discussed is the final scar. All children in this study were scheduled for 6, and 12 months follow-up of the scar, which will be presented separately.

5.4. Limitations of the study

The study has some limitations. Depth of burn and TBSA% were assessed clinically by different burn surgeons, which risks it not being done in a standardised way. Future studies should involve the consistent use of objective assessments, such as laser speckle contrast imaging (LSCI), which is already in use for research at our centre [51–53], or software programs such as BurnCase 3D, which enables more objective calculations of TBSA from digital images [54] to improve diagnostic precision and comparability of groups.

We have previously used wound tracing as a part of the assessments of the time to complete healing [10], and the use of the Visitrak[®] system has often been suggested by other authors. Both methods involve direct contact with the wound bed and rely on the accuracy of “tracers” to draw outlines of wounds [55]. However, as scalds are irregular and located on both concave and convex surfaces, these methods could not be used in a satisfactory way. Attempts to use the Visitrak[®] system have been made in a similar study on burns in children, but because of pain, and the child’s movement, 22% of the measurements

were incomplete and the estimation of healing that was given by the treating consultant was used for the analysis instead [37].

“Blinding” was not possible in this study because of the nature of the porcine xenograft. This might also have introduced bias to the study as it could be argued that physicians may assess a product for which they had a particular liking or were familiar with differently. As the attending nurse also needed to agree on the assessment of healing this bias may have been reduced.

No cost analysis was made because of difficulties in specifying the actual costs. A certain number of dressings for each group cannot be predicted, because healed areas do not require any dressing, and as the dressings are in limited sizes only parts of them may be used and the rest discarded. Porcine xenograft is available at our centre in two sizes; 8 cm × 30 cm and 17 × 46 cm, with a cost/cm² of US\$ 0.43 and US\$ 0.26, respectively. According to the clinical routine, porcine xenograft is applied only once and dressed with Dermanet[®] (US\$ 5.93/unit) and Kerlix[®] (US\$ 1.83/unit) which adds US\$ 7.76 to each dressing change. The silver-foam dressing is available in sizes from 10 cm × 10 cm up to 20 cm × 50 cm at a cost of US\$ 0.05/cm² and is changed at all visits to be able to estimate wound healing. As we do not know the exact burn size in cm² at all visits we cannot calculate the actual cost.

6. Conclusion

We have compared two different dressings for burns (silver-foam and porcine skin) in children with partial-thickness scalds. The primary endpoint (healing time) as well as secondary endpoints (number of dressing changes and time taken for dressing changes) favoured the silver-foam dressing. We found no differences in pain, duration of hospital stay, or rates of infection between dressings. Further studies of long-term differences in outcome (such as scarring) are ongoing.

Declarations of interest

None.

Funding resources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

We give special thanks to Ingmarie Jarnhed Andersson, Anita Sterling Halldin, Chamiran Saume and the rest of the staff at the Linköping Burn Centre, and also to Mats Fredriksson, statistician.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.burns.2019.04.004>.

REFERENCES

- [1] Brusselaers N, et al. Severe burn injury in Europe: a systematic review of the incidence, etiology, morbidity, and mortality. *Crit Care* 2010;14(5):R188.
- [2] Finnerty CC, et al. Hypertrophic scarring: the greatest unmet challenge after burn injury. *Lancet* 2016;388(10052):1427–36.
- [3] Vloemans AF, et al. Optimal treatment of partial thickness burns in children: a systematic review. *Burns* 2014;40(2):177–90.
- [4] Chipp E, et al. A prospective study of time to healing and hypertrophic scarring in paediatric burns: every day counts. *Burns Trauma* 2017;5:3.
- [5] Lonie S, Baker P, Teixeira RP. Healing time and incidence of hypertrophic scarring in paediatric scalds. *Burns* 2017;43(3):509–13.
- [6] Wasiak J, et al. Dressings for superficial and partial thickness burns. *Cochrane Database Syst Rev* 2013;(3):Cd002106.
- [7] Aronoff M, Fleishman P, Simon DL. Experience in the application of porcine xenografts to split-graft donor sites. *J Trauma* 1976;16(4):280–3.
- [8] Chiu T, Burd A. “Xenograft” dressing in the treatment of burns. *Clin Dermatol* 2005;23(4):419–23.
- [9] Morris DM, Hall GM, Elias EG. Porcine heterograft dressings for split-thickness graft donor sites. *Surg Gynecol Obstet* 1979;149(6):893–4.
- [10] Karlsson M, et al. Dressing the split-thickness skin graft donor site: a randomized clinical trial. *Adv Skin Wound Care* 2014;27(1):20–5.
- [11] Burkey B, Davis [78_TD\$DIFF]3rd W, Glat PM. Porcine xenograft treatment of superficial partial-thickness burns in paediatric patients. *J Wound Care* 2016;25(2):S10–5.
- [12] Troy J, et al. The use of EZ Derm(R) in partial-thickness burns: an institutional review of 157 patients. *Eplasty* 2013;13:e14.
- [13] Vanstraelen P. Comparison of calcium sodium alginate (KALTOSTAT) and porcine xenograft (E-Z DERM) in the healing of split-thickness skin graft donor sites. *Burns* 1992;18(2):145–8.
- [14] Salisbury RE, et al. Biological dressings for skin graft donor sites. *Arch Surg* 1973;106(5):705–6.
- [15] Breach NM, Davies DM, Yiacooumettis A. Study of effects of porcine skin and bovine dermis on the healing of split-skin graft donor sites in humans. *Plast Reconstr Surg* 1979;63(4):546–9.
- [16] Karlsson M, et al. Scarring at donor sites after split-thickness skin graft: a prospective, longitudinal, randomized trial. *Adv Skin Wound Care* 2018;31(4):183–8.
- [17] Fishman JA. Infectious disease risks in xenotransplantation. *Am J Transplant* 2018;18(8):1857–64.
- [18] Fishman JA, Scobie L, Takeuchi Y. Xenotransplantation-associated infectious risk: a WHO consultation. *Xenotransplantation* 2012;19(2):72–81.
- [19] Jenkins ED, et al. Informed consent: cultural and religious issues associated with the use of allogeneic and xenogeneic mesh products. *J Am Coll Surg* 2010;210(4):402–10.
- [20] Eriksson A, Burcharth J, Rosenberg J. Animal derived products may conflict with religious patients' beliefs. *BMC Med Ethics* 2013;14:48.
- [21] Enoch S, Shaaban H, Dunn KW. Informed consent should be obtained from patients to use products (skin substitutes) and dressings containing biological material. *J Med Ethics* 2005;31(1):2–6.
- [22] Paddock HN, et al. A silver impregnated antimicrobial dressing reduces hospital length of stay for pediatric patients with burns. *J Burn Care Res* 2007;28(3):409–11.
- [23] Lund , Browder NC. The estimation of areas of burns. *Surg Gynaecol Obstet* 1944;(79):352–8.
- [24] Levine NS, et al. The quantitative swab culture and smear: a quick, simple method for determining the number of viable aerobic bacteria on open wounds. *J Trauma* 1976;16(2):89–94.
- [25] Elmasry M, et al. Changes in patterns of treatment of burned children at the Linköping burn centre, Sweden, 2009–2014. *Burns* 2017;43(5):1111–9.
- [26] Elmasry M, et al. Treatment of children with scalds by xenografts: report from a Swedish burn centre. *J Burn Care Res* 2016;37(6):e586–91.
- [27] de Graaf E, et al. Partial-thickness scalds in children: a comparison of different treatment strategies. *Burns* 2017;43(4):733–40.
- [28] Hundeshagen G, et al. A prospective, randomized, controlled trial comparing the outpatient treatment of pediatric and adult partial-thickness burns with suprathel or mepilex Ag. *J Burn Care Res* 2018;39(2):261–7.
- [29] Bugmann P, et al. A silicone-coated nylon dressing reduces healing time in burned paediatric patients in comparison with standard sulfadiazine treatment: a prospective randomized trial. *Burns* 1998;24(7):609–12.
- [30] Brown NJ, et al. Predictors of re-epithelialization in pediatric burn. *Burns* 2014;40(4):751–8.
- [31] Kokki A, et al. Validation of the parents' postoperative pain measure in Finnish children aged 1–6 years. *Scand J Caring Sci* 2003;17(1):12–8.
- [32] Merkel S, Voepel-Lewis T, Malviya S. Pain assessment in infants and young children: the FLACC scale. *Am J Nurs* 2002;102(10):55–8.
- [33] Gandhi M, et al. Management of pain in children with burns. *Int J Pediatr* 2010;2010:.
- [34] Steinvall I, Karlsson M, Elmasry M. C-reactive protein response patterns after antibiotic treatment among children with scalds. *Burns* 2018;44(3):718–23.
- [35] Greenhalgh DG, et al. American Burn Association consensus conference to define sepsis and infection in burns. *J Burn Care Res* 2007;28(6):776–90.
- [36] Tang H, et al. An open, parallel, randomized, comparative, multicenter investigation evaluating the efficacy and tolerability of Mepilex Ag versus silver sulfadiazine in the treatment of deep partial-thickness burn injuries. *J Trauma Acute Care Surg* 2015;78(5):1000–7.
- [37] Gee Kee EL, et al. Randomized controlled trial of three burns dressings for partial thickness burns in children. *Burns* 2015;41(5):946–55.
- [38] Silverstein P, et al. An open, parallel, randomized, comparative, multicenter study to evaluate the cost-effectiveness, performance, tolerance, and safety of a silver-containing soft silicone foam dressing (intervention) vs silver sulfadiazine cream. *J Burn Care Res* 2011;32(6):617–26.
- [39] Heinrich M, et al. Conscious sedation: off-label use of rectal S (+)-ketamine and midazolam for wound dressing changes in paediatric heat injuries. *Eur J Pediatr Surg* 2004;14(4):235–9.
- [40] van der Heijden MJE, et al. Assessing and addressing the problem of pain and distress during wound care procedures in paediatric patients with burns. *Burns* 2018;44(1):175–82.
- [41] Ashburn MA. Burn pain: the management of procedure-related pain. *J Burn Care Rehabil* 1995;16(3 Pt 2):365–71.
- [42] Barras F, Aussel L, Ezraty B. Silver and antibiotic, new facts to an old story. *Antibiotics (Basel)* 2018;7(3):.
- [43] Davies P, McCarty S, Hamberg K. Silver-containing foam dressings with Safetac: a review of the scientific and clinical data. *J Wound Care* 2017;26(Sup6a):S1–S32.
- [44] Lin YH, et al. Silver-based wound dressings reduce bacterial burden and promote wound healing. *Int Wound J* 2016;13(4):505–11.
- [45] Szweida P, Gorczyca G, Tylingo R. Comparison of antimicrobial activity of selected, commercially available wound dressing materials. *J Wound Care* 2018;27(5):320–6.

-
- [46] Barrett S. Mepilex Ag: an antimicrobial, absorbent foam dressing with Safetac technology. *Br J Nurs* 2009;18(20):s30-6 p. S28.
- [47] Park HS, et al. Early pathogenic colonisers of acute burn wounds: a retrospective review. *Burns* 2017;43(8):1757–65.
- [48] Aziz Z, Abu SF, Chong NJ. A systematic review of silver-containing dressings and topical silver agents (used with dressings) for burn wounds. *Burns* 2012;38(3):307–18.
- [49] Storm-Versloot MN, et al. Topical silver for preventing wound infection. *Cochrane Database Syst Rev* 2010;(3):Cd006478.
- [50] Chiu T, Shah M. Porcin xenograft dressing for facial burns: beware of the mesh imprint. *Burns* 2002;28(3):279–82.
- [51] Mirdell R, et al. Accuracy of laser speckle contrast imaging in the assessment of pediatric scald wounds. *Burns* 2017.
- [52] Mirdell R, et al. Accuracy of laser speckle contrast imaging in the assessment of pediatric scald wounds. *Burns* 2018;44(1):90–8.
- [53] Mirdell R, et al. Microvascular blood flow in scalds in children and its relation to duration of wound healing: a study using laser speckle contrast imaging. *Burns* 2016;42(3):648–54.
- [54] Tocco-Tussardi I, Presman B, Huss F. Want correct percentage of TBSA Burned? Let a Layman do the assessment. *J Burn Care Res* 2018;39(2):295–301.
- [55] Chang AC, Dearman B, Greenwood JE. A comparison of wound area measurement techniques: visitrak versus photography. *Eplasty* 2011;11:e18.