



PERSPECTIVE ARTICLE

# Tissue-Engineered Approaches for Complex Wounds: A Case Series Using Esterified Hyaluronic Acid Matrix.

Robin Evans<sup>1</sup>, William Starr<sup>1</sup>, Shreyash Prahdan<sup>2</sup>, Javier Romero<sup>1</sup>, Graal Diaz<sup>2</sup>

<sup>1</sup>Anacapa Surgical Associates  
Ventura County Health Care  
Agency 300 Hillmont Ave.,  
Ventura, CA, USA, 93003

<sup>2</sup>Graduate Medical Division  
Community Memorial Healthcare  
System 147 N. Brent St., Ventura,  
CA, 93003



OPEN ACCESS

## PUBLISHED

31 August 2025

## CITATION

Evans, R., Starr, W., Prahdan, S.,  
et al. Tissue-Engineered Approaches  
for Complex Wounds: A Case  
Series Using Esterified Hyaluronic  
Acid Matrix. Medical Research  
Archives, [online] 13(8).

<https://doi.org/10.18103/mra.v13i8.6614>

## COPYRIGHT

© 2025 European Society of  
Medicine. This is an open- access  
article distributed under the  
terms of the Creative Commons  
Attribution License, which permits  
unrestricted use, distribution, and  
reproduction in any medium,  
provided the original author and  
source are credited.

## DOI

<https://doi.org/10.18103/mra.v13i8.6614>

## ISSN

2375-1924

## ABSTRACT

**Background:** Complex soft tissue injuries are difficult to heal and costly to treat. Current solutions are often insufficient to heal complex wounds. Tissue engineering for acute wounds is a new approach. Tissue engineering focuses on regenerating tissue based on the use of biologic scaffolds and cell signalling. New technologies use a tissue engineering approach to ensure a smooth transition between the phases of wound healing. Hyaluronic Acid (HA) has become a recent focus of interest. This study aimed to review the experience of patients treated with electrospun non-woven cross-linked hyaluronic acid matrix (eHAM) in the management of acute and chronic wounds.

**Methods:** A case series study was performed of consecutive adults (age >18 years old) treated with eHAM to manage their wound within an 18-month period. Data were analysed for demographic information and time to healing.

**Results:** 12 cases with full thickness wound depths were found in the 16 months of the study. Wound size for all patients decreased after the first eHAM application with mean delta wound size -56.99 cm<sup>2</sup>; 66.67% had a second eHAM application, 25% had a third eHAM application. 41.67% patients healed using just eHAM therapy.

**Conclusion:** Our preliminary experience demonstrates that electrospun non-woven cross-linked hyaluronic acid matrix (eHAM) is a valuable tool to assist in the healing of complex wounds. In our study, many patients were able to heal using eHAM therapy alone. Clinical benefit was demonstrated after first eHAM application, where wound size was markedly reduced for all patients.

## Introduction

Complex soft tissue injuries are difficult to heal and costly to treat. Current solutions are often insufficient to heal complex wounds. Tissue engineering for acute wounds is a new approach<sup>1</sup>. Tissue engineering focuses on regenerating tissue based on the use of biologic scaffolds and cell signaling. Normal wound healing is a dynamic, multiple-phase process that requires coordinated interactions between inflammatory factors, growth factors, angiogenesis, and collagen formation<sup>2</sup>. New technologies use a tissue engineering approach to ensure a smooth transition between the phases of wound healing. If an acute wound fails to progress through normal wound healing phases, it can become a chronic wound<sup>3</sup>.

For example, negative wound pressure therapy has gained popularity because of its effects on angiogenesis<sup>4</sup>. Through inducing angiogenesis, the time to healing is improved, and chronic wounds have been shown to develop healthy granulation tissue<sup>5</sup>. However, negative wound pressure dressings require specialized care, and significant community support structures unavailable to many patients. As well, stimulating angiogenesis is only one component of successful wound healing. As such, a new tissue engineering approach is required to treat a wider variety of wounds at all stages.

Hyaluronic Acid (HA) has become a recent focus of interest. HA is a critical component in healthy skin<sup>6</sup>. HA is a non-sulfated glycosaminoglycan (GAG) found in the extracellular matrix of the skin and soft tissue. It is comprised of repeating polymeric disaccharides of D-glucuronic acid and N-acetyl-D glucosamine linked by a glucuronic  $\beta$  (1-3) bond<sup>7</sup>. Depending on the HA size, salt concentration, pH, and associated cations, HA has a different physiologic effect<sup>8,9</sup>.

HA is a key component in successful wound healing<sup>10</sup> as it modifies cell signaling. HA is involved in several different roles. Immediately after injury, hemostasis needs to occur<sup>9</sup>. To

accomplish this, high-molecular-weight hyaluronic acid (HMW-HA) is released from platelets. HA recruits neutrophils to perform phagocytosis of debris and dead tissue and release tumor necrosis factor-alpha (TNF- $\alpha$ ), IL-1 $\beta$ , and IL-8<sup>11</sup>. HA has also been shown to interact with the toll-like receptors (TLR2 and TLR 4) or lymphocytes and macrophages<sup>12,13</sup>. Fibronectin and HA help to guide fibroblasts to the wound<sup>14</sup> and support the formation of type III collagen and a new ECM<sup>15</sup>. HA has also been noted to have a role in scarless, fetal wound healing<sup>16</sup>.

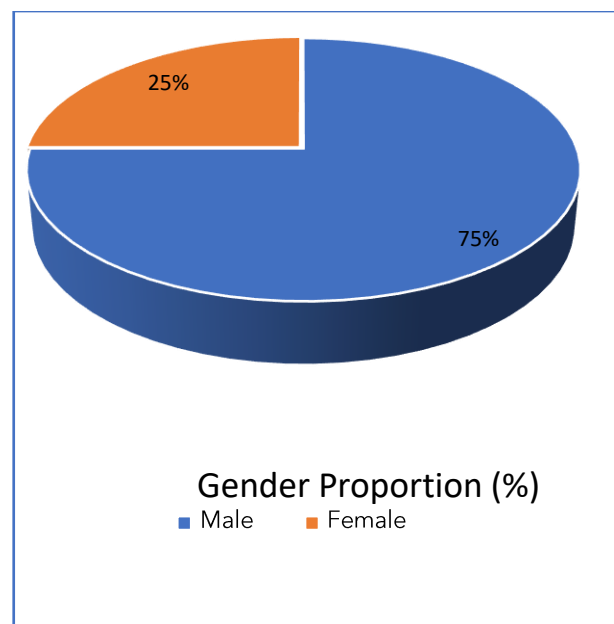
Uniquely, HA also has excellent properties as a scaffold. Esterified HA has been developed to utilize this characteristic<sup>13,17</sup>. Esterification allows for improved hydrophobicity and reduces HA degradation<sup>18</sup>. The electrospun membrane of esterified HA is covered with silicone sheeting. Currently marketed as Hyalomatrix by Medline, this esterified hyaluronic acid matrix was initially used to treat burns<sup>19</sup>. The objective of the current study is to review our current experience to determine future research directions.

## Methods:

This was a single-center, prospective case-series conducted at a Level II trauma center over 16 months (February 2021 to September 2022). Eligible participants were consecutive adults aged 18 years or older treated with eHAM for wounds during the study window; exclusions included use of eHAM outside the study indications, incomplete medical records preventing key data extraction, or loss to follow-up before healing could be ascertained. Intervention details followed the manufacturer's protocol and local practice, with documentation on whether eHAM served as the primary modality or an adjunct, frequency of dressing changes, device settings, and any adjunctive therapies (debridement, antibiotics, negative-pressure therapy, grafting) with timing relative to eHAM. Clinician training adhered to institutional guidelines, and deviations from the protocol were recorded. Data were abstracted

from the electronic medical record and wound-care logs by trained staff using a predefined form and data dictionary. Quality assurance included double data entry for critical fields and regular source-note verification with adjudication of discrepancies. Variables collected encompassed demographics and wound characteristics (location, mechanism, injury date, size in cm<sup>2</sup>, depth, prior treatments, skin grafting dates and type, dates of eHAM applications and re-applications. Outcomes included the primary time to wound healing (defined as complete epithelialization with no drainage) and secondary outcomes such as percent wound size reduction, need for grafting, complications, and days to milestones. Follow-up extended from the first eHAM application to healing or last contact. Wound size and depth were measured using standardized methods; clinicians determined healing. Statistical analyses used SAS 9.4. Descriptive statistics described variables; time-to-event analyses employed Kaplan-Meier estimates with median time to healing and 95% CIs, and bivariate tests for subgroup comparisons. The study received IRB approval, with no external funding.

Figure 1. Participants by gender



## Results:

In this cohort of 12 consecutive adults with full-thickness wounds treated with the esterified hyaluronic acid matrix (eHAM), the tables summarize wound-size changes, injury location, timing, and subsequent interventions. Table 1 shows that initial wound sizes ranged widely (4 to 2000 cm<sup>2</sup>). After the first eHAM application, 11 of 12 wounds decreased in size, while two wounds showed no change (initial 360 cm<sup>2</sup> remaining 360 cm<sup>2</sup>; initial 16 cm<sup>2</sup> remaining 16 cm<sup>2</sup>). The individual delta sizes ranged from a small reduction of 0 to a substantial reduction of 425 cm<sup>2</sup>, with percent decreases after the first eHAM spanning 0% to 77.8%. The mean decrease across all wounds after the first eHAM was 56.99 cm<sup>2</sup>, corresponding to an average 30.5% reduction in wound area (mean initial 244.6 cm<sup>2</sup>; mean post-eHAM 187.6 cm<sup>2</sup>).

Table 1. Wound Size Difference (sq.cm) Upon Treatment with First Esterified Hyaluronic Acid Matrix (eHAM).

Patient ID	Initial Wound Size	Post eHAM Wound Size	*Delta Wound Size	Percent Decrease in Wound Size After First eHAM Application
	7	6	-1	14.29
2	42	24	-18	42.86
3	11.2	5	-6.2	55.36
4	160	120	-40	25
5	360	360	0	0
6	2000	1575	-425	21.25
7	16	16	0	0
8	48	36	-12	25
9	72	16	-56	77.78
10	160	48	-112	70
11	4	3.6	-0.4	10
12	55.3	42	-13.3	24.05

Note. Delta Wound Size represents the difference in size (sq. cm) between the initial wound size measured and the wound size after the first eHAM was applied. A negative value for Delta Wound Size indicates that the wound surface area became smaller upon applying the first eHAM; a positive value would indicate the opposite.

Figure 2. Right hand crush burn injury from a conveyor belt: A. Tangential excision, exposed tendons, skin graft; B. Debridement, eHAM application; C. Debridement, and skin graft; D. Final result

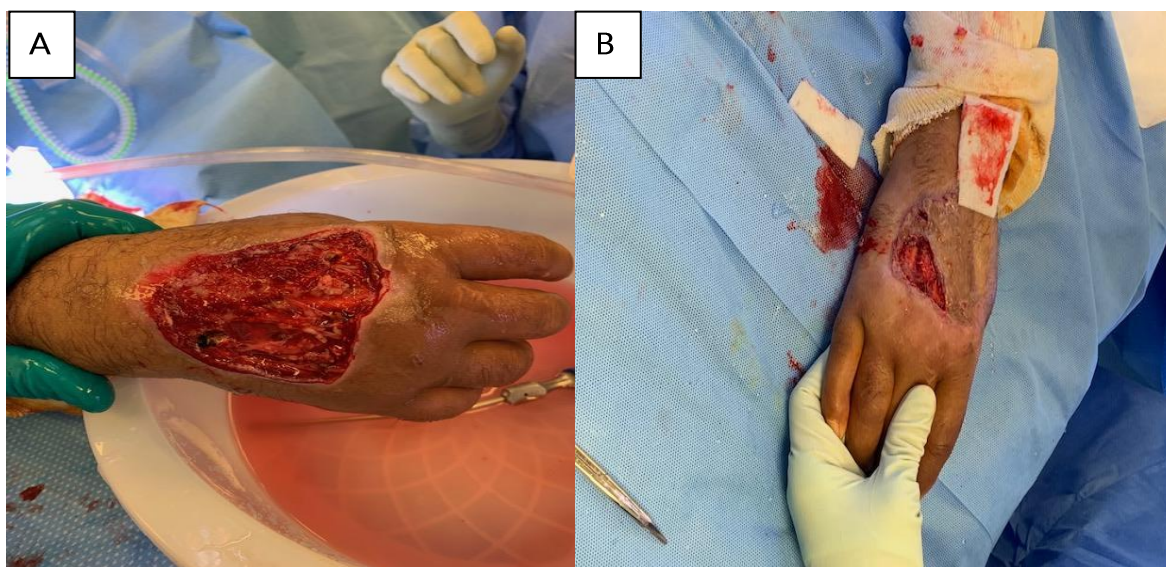






Table 2 groups wounds by area of injury. Head and neck wounds (n=4) had a mean initial size of 16.05 cm<sup>2</sup>, a mean delta of -6.4 cm<sup>2</sup>, and a mean 30.6% reduction, with healing averaging 56 days. Upper extremity wounds (n=1) measured 55.3 cm<sup>2</sup> initially, decreasing by 13.3 cm<sup>2</sup> (24.05% decrease)

and healing in 25 days. The trunk wound (n=1) began at 2000 cm<sup>2</sup>, decreased by 425 cm<sup>2</sup> (21.25%), and healed in 133 days. Lower extremity wounds (n=6) started at a mean 136 cm<sup>2</sup>, with a mean delta of -36.67 cm<sup>2</sup> and a 32.96% reduction, healing over about 74.5 days.

Table 2. Table of Summaries by Area of Injury.

Location	(N)	Mean Initial Wound Size (cm <sup>2</sup> )	Mean *Delta Wound Size(cm <sup>2</sup> )	Mean Percent Decrease of Wound Size after 1 <sup>st</sup> eHAM	Mean Time (days) from eHAM to Healed
Head and Neck	4	16.05	-6.4	30.63	56
Upper Extremity	1	55.3	-13.3	24.05	25
Trunk	1	2000	-425	21.25	133
Lower Extremity	6	136	-36.67	32.96	74.5

\*Delta Wound Size represents the difference in size (sq.cm) between the initial wound size measured and the wound size after the first eHAM was applied. A negative value for Delta Wound Size indicates that the wound surface area became smaller upon application of the first eHAM; a positive value would indicate the opposite.

Figure 3. Recurrent basal cell carcinoma of nasal dorsum: A. Moh's micrographic surgery defect; B. First eHAM application; C. Third eHAM D; Healed wound



Table 3 provides the overall picture: mean age was 52.25 years (SD 23.44). Time from wound onset to first eHAM averaged 27.4 days (SD 26.4). Initial wounds averaged 244.6 cm<sup>2</sup> (SD 562.1), with post-first-eHAM wounds averaging 187.6 cm<sup>2</sup> (SD

448.1) and a mean delta of -56.99 cm<sup>2</sup> (SD 12.46). The mean percent decrease after the first eHAM was 30.47% (SD 25.76), and the time from eHAM to healed averaged 69.1 days (SD 36.5).

Table 3. Wound Size Difference (square centimeters) Upon Treatment.

Variable	Mean(Standard Deviation)
Age	52.25 (23.44)
Days from wound to 1st eHAM	27.42 (26.44)
Initial Wound Size (sq.cm)	244.62 (562.1)
Wound Size After 1st eHAM (sq.cm)	187.6 (448.1)
Delta Wound Size (sq.cm)	-56.99 (12.46)
Percent Decrease in Wound Size After 1 <sup>st</sup> eHAM Application	30.47 (25.76)
Days from eHam to Healed	69.08 (36.45)

Table 4 describes treatments: all patients received a first eHAM, eight (66.7%) received a second, and three (25%) a third. First skin grafts were performed in 7 patients (58.3%), with a second graft in 5 patients (41.7%).

Table 4. Treatments Received.

Treatments	Yes (N, %)	No (N, %)
1st eHAM	12 (100%)	0 (0%)
2nd eHAM	8 (66.67%)	4 (33.33%)
3rd eHAM	3 (25%)	9 (75%)
1st Skin Graft	7 (58.33%)	5 (41.67%)
2nd Skin Graft	5 (41.67%)	7 (58.33%)

## Discussion:

**The development of eHAM.** Tissue engineering is an emerging interdisciplinary field that applies principles of bioengineering and life sciences to develop substitutes that guide tissue regeneration. Langer and Vacanti<sup>20</sup> categorized three components that govern the outcome of

tissue-engineered constructs: scaffolding, instructive environment, and responsive cells. Tissues are engineered in one of two ways: fabricated matrices or the use of cultured human epithelial cells. In the 1980s, the replacement of skin with cells in collagen-glycosaminoglycan scaffolds to facilitate tissue formation was gaining traction. Burke et al.<sup>21</sup> successfully used porous collagen-chondroitin fibrillar dermis to physiologically promote wound healing in burn patients. Most of the early foundations of tissue engineering relied on the use of human cell cultures.

The development of cultured human epithelial autografts (CEA)<sup>22</sup> was a major advance in tissue engineering. However, cultured autografts were found to be fragile and expensive<sup>23</sup>. The dermal-epidermal junction requires a biocompatible scaffold to help these cells to grow effectively. Hyaluronic acid was a biocompatible molecule and potential scaffold for CEA. Initially, the ethyl and n-propyl esters of hyaluronic were used to create a polymer film and show the biocompatibility of the approach<sup>24</sup>. Zacchi et al.<sup>25</sup> cultured fibroblasts and keratinocytes on a non-woven scaffold of a benzyl



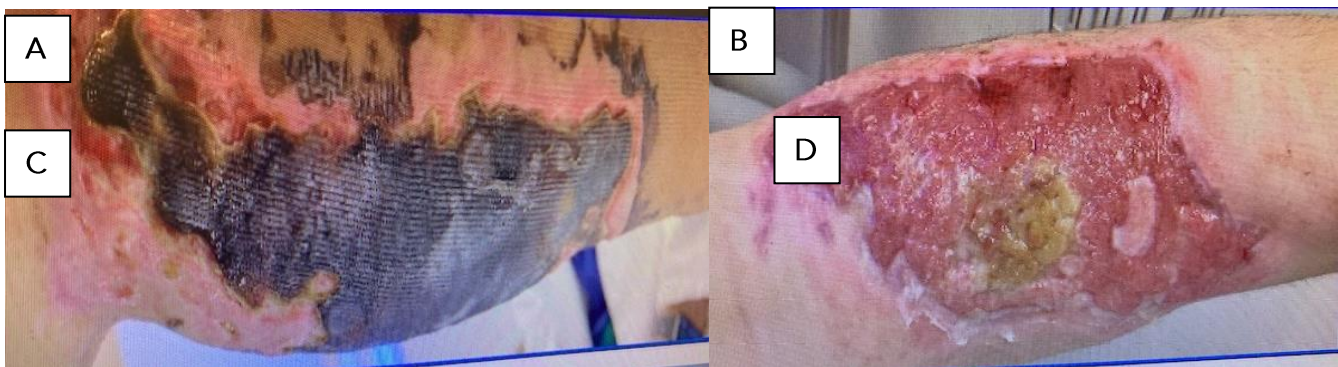
ester of hyaluronic acid to re-create the epidermal-dermal junction seen in normal skin. Galassi et al.<sup>26</sup> used this approach to show an increase in the reconstruction of autologous ECM in both acute and chronic wounds.

Biodegradable temporizing matrices (BTM) have gained popularity in the treatment of acute burn wounds. Early burn debridement has been shown to improve outcomes<sup>27-31</sup>. However, the extent of debridement can be limited by the availability of skin graft donor sites, especially in large burns. BTM such as eHAM provides alternatives for early coverage. Gravante et al. demonstrated eHAM use in deep partial thickness<sup>32</sup> and full thickness<sup>18</sup> burn patients. Some of these patients went on to heal without skin grafting. A silicone sheet bilayer in these patients theoretically improves fluid loss and granulation tissue formation monitoring. Osti and Enzo<sup>33</sup> found an improvement in wound pH after eHAM application, suggesting improvement in burn healing through alteration of cell signalling. Specifically, it appears that hyaluronic acid plays a

role via specific HA receptors, inflammation, cellular migration, and angiogenesis<sup>34</sup>.

**The clinical use of eHAM for complex wounds.** Even complex wounds benefit from eHAM application. Complex wounds include wounds with exposed bone, tendon, or other difficult-to-heal clinical situations such as diabetic foot wounds. These unique wounds pose a challenge to any clinician. Notably, the exposure of tendon or bone can lead to tendon necrosis and osteomyelitis, respectively. Ultimately increased delayed healing, morbidity, and mortality. As well, there are often limited dressing and clinical options. A skin graft does not have the ability to take without a blood supply from its recipient site and a local, regional, or free flap is often required. Although negative wound pressure therapy (NWPT) has been successfully employed in the treatment of complex wounds<sup>35</sup>, it is painful, expensive, and requires a bulky machine to be attached to the wound at all times.

Figure 4. Full thickness skin loss of calf after cast removal for a closed tibial fracture: A. Eschar managed with Silvadene dressing (20 cm x 8 cm); B. Sloughed off eschar; C. Calf after removal of eHAM for 3 weeks (14.5 cm x 6 cm); D. Calf 60 days after eHAM application



Liu et al. illustrated the effectiveness of eHAM in patients with exposed tendon or bone from trauma, chronic wounds, diabetic foot wounds, and burns<sup>36</sup>. In this series, eHAM was used for approximately three weeks and followed by coverage with split-thickness skin grafting. However, multiple applications of eHAM have also been used. Vamenti et al. has shown that multiple applications of eHAM improve wound healing

outcomes<sup>37</sup>. This includes healing by secondary intention and preparation for skin grafting.

The primary therapeutic aim of esterified hyaluronic acid matrix (eHAM) in complex wounds is to induce the formation of a neodermis—a dermal-like, organized tissue that serves as an integrative bed for subsequent healing steps. This neodermis was first identified through work by Myers and colleagues, who described a distinct



tissue resulting from the interaction of the eHAM scaffold with host tissue. The neodermis forms as a product of HA signaling within the matrix, promoting a cascade of cellular events that culminate in a highly vascularized, structurally organized layer that more closely resembles native dermis than conventional granulation tissue.

Histologically, the neodermis appears more organized and vascular than typical granulation tissue, with Aballey and colleagues reporting that the dermal characteristics within the neodermis resemble those of normal skin dermis. The extended vascular network supports robust perfusion and nutrient delivery, which is particularly important in wounds with exposed structures such as tendons and bones, where a stable, well-vascularized bed is essential for protection and healing. The neodermis thus provides a durable, scaffold-like foundation that accommodates re-epithelialization and enhances graft take, enabling skin grafts to adhere and integrate more reliably and potentially reducing the need for more complex flap coverage in some cases.

In essence, eHAM's value lies not only in temporary wound coverage but in actively guiding tissue remodeling toward a dermal substitute that supports stability, vascularity, and subsequent epidermal regeneration. While the precise extent and kinetics of neodermis formation can be influenced by factors such as infection, perfusion, and patient comorbidities, the concept underscores how HA-based matrices create a

dermal analogue that bridges the gap between the wound bed and definitive closure.

## Conclusion:

Our experience demonstrates that the electrospun non-woven esterified hyaluronic acid matrix (eHAM) is a valuable tool in the treatment of complex wounds. The nanofibrous scaffold provides increased opportunities for cell adhesion and growth. Matrix revascularization allows for healing by secondary intention or coverage with a skin graft. In our study, many patients were able to heal using eHAM therapy alone. Clinical benefit was demonstrated after the first eHAM application, where wound size was markedly reduced for all patients. Multiple eHAM applications showed improved efficacy in larger wounds. Further investigation will allow us to improve our tissue engineering paradigm to optimize outcomes for patients with complex wounds.

## Conflict of Interest:

None.

## Funding Statement:

This study did not receive funding. Dr. Evans is a member of the Advisory Board of True Digital Surgery, and the rest of the authors have nothing to disclose.

## Acknowledgements:

None

## References:

1. Vig, K. et al. Advances in skin regeneration using tissue engineering. *International journal of molecular sciences* **18**, 789 (2017).
2. Sinno, H. & Prakash, S. Complements and the wound healing cascade: an updated review. *Plastic surgery international* **2013** (2013).
3. Krzyszczyk, P., Schloss, R., Palmer, A. & Berthiaume, F. The role of macrophages in acute and chronic wound healing and interventions to promote pro-wound healing phenotypes. *Frontiers in physiology* **9**, 419 (2018).
4. Glass, G., Murphy, G., Esmaili, A., Lai, L. M. & Nanchahal, J. Systematic review of molecular mechanism of action of negative-pressure wound therapy. *British Journal of Surgery* **101**, 1627-1636 (2014).
5. Bassetto, F. et al. Histological evolution of chronic wounds under negative pressure therapy. *Journal of plastic, reconstructive & aesthetic surgery* **65**, 91-99 (2012).
6. Papakonstantinou, E., Roth, M. & Karakiulakis, G. Hyaluronic acid: A key molecule in skin aging. *Dermato-endocrinology* **4**, 253-258 (2012).
7. Weissmann, B., Meyer, K., Sampson, P. & Linker, A. Isolation of oligosaccharides enzymatically produced from hyaluronic acid. *Journal of Biological Chemistry* **208**, 417-429 (1954).
8. Fallacara, A., Baldini, E., Manfredini, S. & Vertuani, S. Hyaluronic acid in the third millennium. *Polymers* **10**, 701 (2018).
9. Tavianatou, A. G. et al. Hyaluronan: molecular size-dependent signaling and biological functions in inflammation and cancer. *FEBS J* **286**, 2883-2908, doi:10.1111/febs.14777 (2019).
10. Neuman, M. G., Nanau, R. M., Oruña-Sánchez, L. & Coto, G. Hyaluronic acid and wound healing. *Journal of Pharmacy & Pharmaceutical Sciences* **18**, 53-60 (2015).
11. Graca, M. F. P., Miguel, S. P., Cabral, C. S. D. & Correia, I. J. Hyaluronic acid-Based wound dressings: A review. *Carbohydr Polym* **241**, 116364, doi:10.1016/j.carbpol.2020.116364 (2020).
12. Aya, K. L. & Stern, R. Hyaluronan in wound healing: rediscovering a major player. *Wound repair and regeneration* **22**, 579-593 (2014).
13. Chen, W. J. in *Hyaluronan* 147-156 (Elsevier, 2002).
14. Webber, J., Jenkins, R. H., Meran, S., Phillips, A. & Steadman, R. Modulation of TGFβ1-dependent myofibroblast differentiation by hyaluronan. *The American journal of pathology* **175**, 148-160 (2009).
15. Stern, R., Asari, A. A. & Sugahara, K. N. Hyaluronan fragments: an information-rich system. *European journal of cell biology* **85**, 699-715 (2006).
16. Longaker, M. T. et al. Studies in fetal wound healing. V. A prolonged presence of hyaluronic acid characterizes fetal wound fluid. *Annals of surgery* **213**, 292 (1991).
17. Harding, K. (Elsevier BV, 2000).
18. Gravante, G. et al. Hyalomatrix PA in burn care practice: results from a national retrospective survey, 2005 to 2006. *Ann Plast Surg* **64**, 69-79, doi:10.1097/SAP.0b013e31819b3d59 (2010).
19. Longinotti, C. The use of hyaluronic acid based dressings to treat burns: A review. *Burns & trauma* **2**, 2321-3868.142398 (2014).
20. Langer, R., Lanza, R., Langer, R. S. & Vacanti, J. P. *Principles of tissue engineering*. (Academic Press, 2000).
21. Burke, J. F., Yannas, I. V., Quinby Jr, W. C., Bondoc, C. C. & Jung, W. K. Successful use of a physiologically acceptable artificial skin in the treatment of extensive burn injury. *Annals of surgery* **194**, 413 (1981).
22. Green, H., Kehinde, O. & Thomas, J. Growth of cultured human epidermal cells into multiple epithelia suitable for grafting. *Proceedings of the National Academy of Sciences* **76**, 5665-5668 (1979).
23. Atiyeh, B. S. & Costagliola, M. Cultured epithelial autograft (CEA) in burn treatment: three decades later. *Burns* **33**, 405-413 (2007).

24. Cortivo, R., Brun, P., Rastrelli, A. & Abatangelo, G. In vitro studies on biocompatibility of hyaluronic acid esters. *Biomaterials* **12**, 727-730 (1991).
25. Zacchi, V. et al. In vitro engineering of human skin-like tissue. *Journal of Biomedical Materials Research: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and the Australian Society for Biomaterials* **40**, 187-194 (1998).
26. Galassi, G. et al. In vitro reconstructed dermis implanted in human wounds: degradation studies of the HA-based supporting scaffold. *Biomaterials* **21**, 2183-2191 (2000).
27. Janzekovic, Z. A new concept in the early excision and immediate grafting of burns. *The Journal of trauma* **10**, 1103-1108 (1970).
28. Janzekovic, Z. Early surgical treatment of the burned surface. (1972).
29. Burke, J. F., Bondoc, C. C. & Quinby, W. C. Primary burn excision and immediate grafting: a method shortening illness. *Journal of Trauma and Acute Care Surgery* **14**, 389-395 (1974).
30. Herndon, D. N. et al. A comparison of conservative versus early excision. Therapies in severely burned patients. *Annals of surgery* **209**, 547 (1989).
31. Desai, M. H. et al. Early burn wound excision significantly reduces blood loss. *Annals of surgery* **211**, 753 (1990).
32. Gravante, G. et al. The use of Hyalomatrix PA in the treatment of deep partial-thickness burns. *Journal of burn care & research* **28**, 269-274 (2007).
33. Osti, E. Skin pH variations from the acute phase to re-epithelialization in burn patients treated with new materials (burnshield®, semipermeable adhesive film, dermasilk®, and hyalomatrix®). Non-invasive preliminary experimental clinical trial. *Annals of burns and fire disasters* **21**, 73 (2008).
34. Litwiniuk, M., Krejner, A., Speyrer, M. S., Gauto, A. R. & Grzela, T. Hyaluronic acid in inflammation and tissue regeneration. *Wounds* **28**, 78-88 (2016).
35. Park, H., Copeland, C., Henry, S. & Barbul, A. Complex wounds and their management. *Surgical Clinics* **90**, 1181-1194 (2010).
36. Liu, X., Dadiredy, K. & Velamuri, S. R. Esterified Hyaluronic Acid Matrix in Lower Extremity Reconstruction With Exposed Tendon and Bone: A Retrospective Review. *Journal of Burn Care & Research* **41** (2020).
37. Vaienti, L. et al. Limb trauma: the use of an advanced wound care device in the treatment of full-thickness wounds. *Strategies in trauma and limb reconstruction* **8**, 111-115 (2013).
38. Myers, S. R., Partha, V. N., Soranzo, C., Price, R. D. & Navsaria, H. A. Hyalomatrix: a temporary epidermal barrier, hyaluronan delivery, and neodermis induction system for keratinocyte stem cell therapy. *Tissue engineering* **13**, 2733-2741 (2007).
39. Aballay, A. & Hermans, M. H. Neodermis formation in full thickness wounds using an esterified hyaluronic acid matrix. *Journal of Burn Care & Research* **40**, 585-589 (2019).