



## New Technique for Reconstructing Fresh Massive Wounds with Skin Flaps in Equine

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### Abstract

**Objective-** To present a new technique of suturing fresh massive wounds with skin flap in equine regardless of the flap direction and/or location.

**Design-** Experimental in vivo study and clinical trial.

**Animals-** Nine healthy donkeys for experimental study and 28 horses with different injuries that varied in shape and location for clinical trial.

**Procedures-** All injuries were repaired using the new technique. Flap survival length and viability were assessed over three week's period both clinically; through observing skin texture and appearance, hair depilation as well as wound healing; and histologically through skin biopsy at 7, 14 and 21 days after surgery to evaluate the healing process.

**Results-** Clinical cases showed excellent wound healing in all flaps. Histologically, all flaps showed good healing by day 7, and at 21 days all the underlying space was filled with normal s.c. tissue.

**Conclusion and Clinical Relevance-** This new technique is a rapid and successful field-procedure for the treatment of fresh massive wounds with skin flap in equine without the need of sophisticated equipments yet with good results.

**Key Words-** Reconstructing, Wound, Skin Flaps, Equine

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## **Introduction**

Most equine skin injuries, including those with significant tissue loss, can be successfully managed with proper therapy.<sup>1</sup> Over the past 30 years, repair of massive skin wounds has passed through many major key-points both in fixation material as well as technique. Initially, large wounds were sutured using wires<sup>2</sup>, after which there was the Velcro closure material<sup>3</sup>, then the stainless steel staples<sup>4</sup> and most recently the fibrin glue.<sup>5</sup> Techniques also differed with various approaches of skin flaps and skin grafts<sup>6-13</sup> and lately the use of tissue expansions where a full-thickness skin covers large skin defects.<sup>14,15</sup> Generally, equine skin wounds have the innate ability to heal rapidly; however, injuries can quickly turn into complicated wounds, given the severity of the inciting trauma and the less than ideal environment in which the horses are housed. Therefore, successful wound management must focus on a combination of timely surgical and medical intervention to ensure the best potential outcome.<sup>1</sup>

The aim of this article was to execute a new technique that can be quickly and easily applied in the field for reconstructing fresh wounds with massive flaps in equine, focusing on the surgical success rate and the resulting cosmeses.

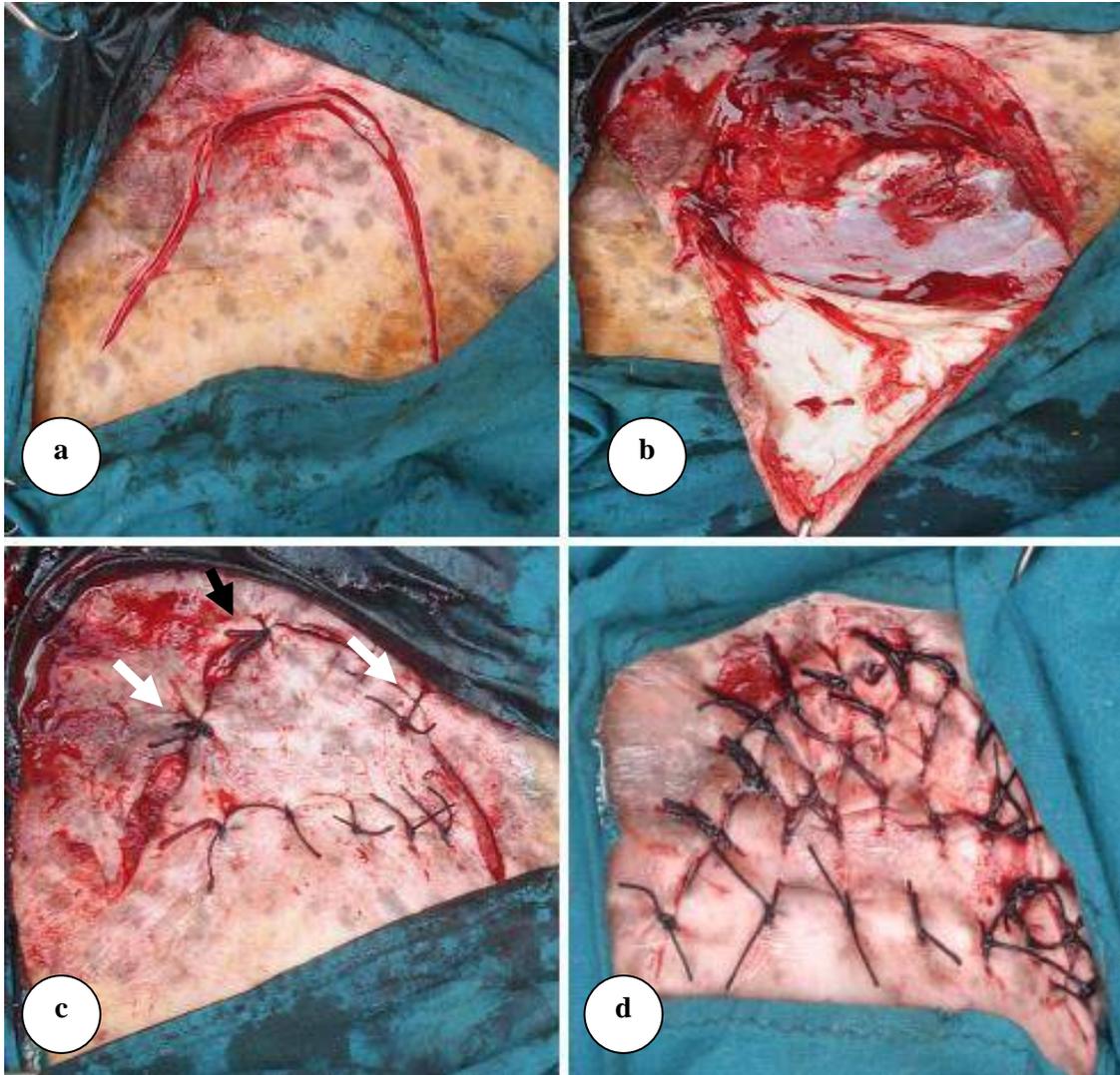
## **Materials and Methods**

This study was done on experimental and clinically injured animals. The experimental part was done on 9 healthy donkeys of both sexes, weighting from 150 to 250 kg. Animals were divided into 3 groups each of 3 animals according to the tissue biopsy time. Induced experimental wounds were of different shapes, sizes and locations simulating the most common field injuries. The clinical trials were conducted on 28 horses of different weights and sexes suffering from different fresh massive skin flap injuries that varied in shape and location. The clinical injuries were located on the arm and forearm, pectoral muscles, thorax, abdomen and thighs. Length and width measurements were taken for all wounds and flaps. All surgeries were freshly performed within the first four hours of injury for the experimental group and within the first eight hours for the clinical ones. Animals were anaesthetized for surgery. The wound bed as well as the skin flap were cleansed with warm normal saline and prepared for suturing.

The skin flap was fixed by non-absorbable suture material from the tip of the flap into the corresponding wound edge. Then two to four stitches were taken to fix the sides of the flap to their corresponding edges of the wound. Absorbable suture material was used to tightly adhere the flap with the underlying tissue leaving no dead space. The suture pattern started from the skin level downwards to include subcutaneous tissue and part of the muscles, then passing horizontally parallel to the wound surface, then up towards the flap surface forming a –U– shape pattern and exiting close to the entry point and knotting. The pattern was repeated evenly distributed all over the flap surface leaving about 1 cm in between (Fig 1).

Postoperative care consisted of a single dose of antitetanic serum and a systemic course of antibiotic. The non-absorbable suture materials were removed after 7-10 days of surgery. Flap survival was assessed macroscopically through observing skin texture, appearance, depilation of hair and wound healing for 21 days after surgery. A 0.5cm x 0.5 cm skin and s.c. tissue biopsy were taken under anaesthesia at 7, 14 and 21 days after surgery from the three experimental groups. Single biopsy/animal from each group was taken. No samples were taken from the

clinical cases. The obtained biopsies were routinely processed, cut at 4-6 microns and stained by H&E for light microscopy.



**Figure 1.** Surgical procedures: **a-** skin incision has been made in an experimental animal; **b-** the flap is reflected and the subcutaneous tissue is exposed; **c-** fixation of the flap started with the tip (black arrow) then the sides (white arrows), then the rest of the flap surface **d-** final result.

## Results

In all cases, wound area size was larger than the corresponding flap size. Wound caused the skin to shrink so that the post-fixation area was on average 90% of the wound area. There was a significant relationship between flap width and viable length. Flaps with length twice the size of the width (2:1) survived perfectly (Fig 2 and 3). Flaps with length trice the size of the width (3:1) survived less perfectly but showed flap-tip necrosis (Fig. 4). The overall success rate of the

experimental and clinical cases was (88.9%, n=8) and (78.6%, n=22) respectively. Flap tip necrosis was seen in 1 case of the experimental groups (11.1%) and in 6 cases of the clinical one (21.4%).

Skin biopsy at one week of surgery, revealed plumbs of active fibroblasts and abundant collagenous fibers filling the gap between the skin and the s.c. tissue. Some areas exhibited inflammatory reactions that were manifested by mononuclear inflammatory cell aggregations mainly macrophages, plasma cells, lymphocytes and polymorph nuclear leucocytes with abundant newly formed blood capillaries (Fig. 5). Two weeks after surgery, more collagen fibers appeared in the site with less inflammatory cellular reaction and the newly formed blood capillaries still existed (Fig. 6). Three weeks after surgery, the area consisted mainly of disorganized collagenous bundles in cross-linked manner and aligned along the tension lines with fewer numbers of fibroblasts which may extended in the subcutaneous tissue,. The area appeared to be homogenous due to the presence of collagenous fibers which were closely intermingled and linked the two sides of the area (Fig. 7).



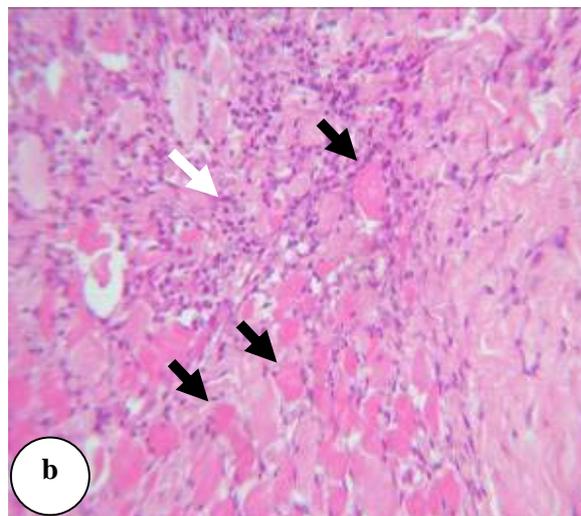
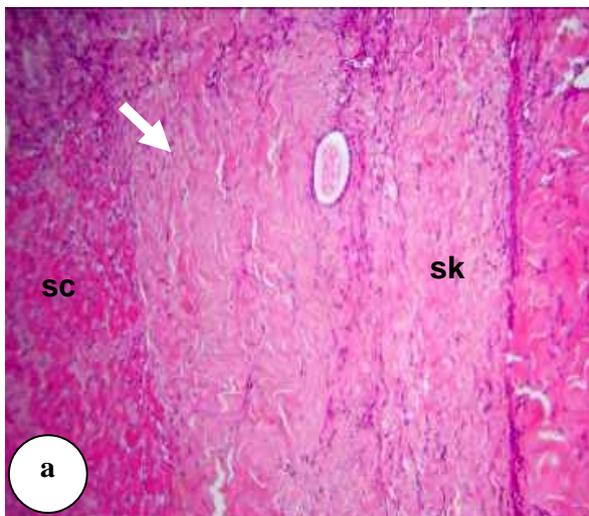
**Figure 2.** Lacerated wound in an experimental case before and after treatment. Note that the skin flap length is double the flap base (2:1).



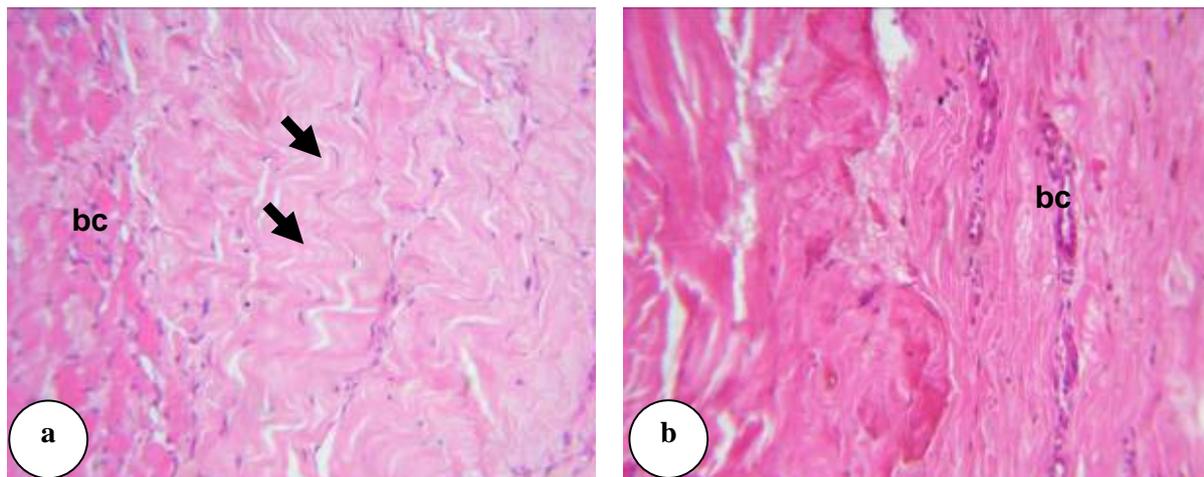
**Figure 3.** Skin wound healing after 10 days before stitch removal. Note the successful healing of the flap.



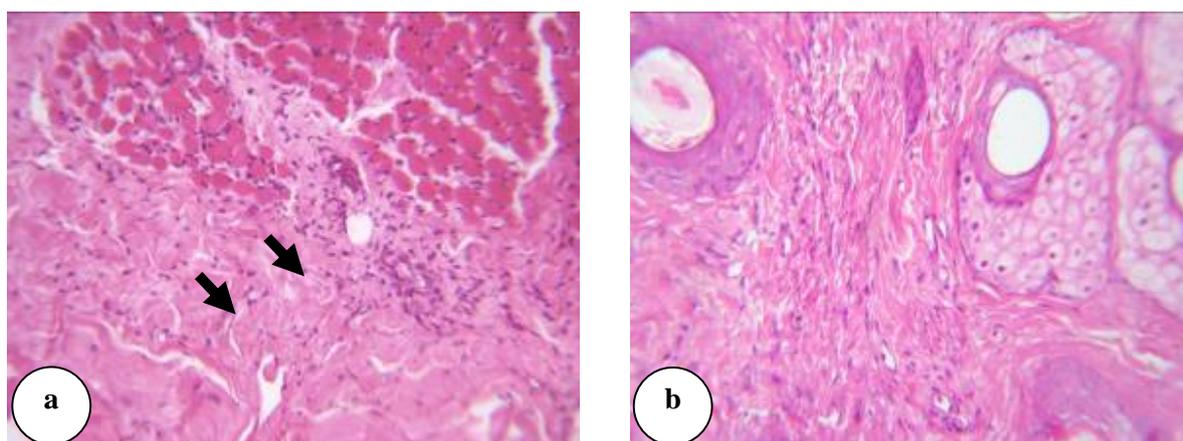
**Figure 4.** Wound dehiscence and flap tip necrosis. Note the black coloration of the flap starting at the free-end of the flap.



**Figure 5.** one week: **a-** plumps of active fibroblasts and abundant collagenous fibers (white arrow) filling the gap between the skin (sk) and the subcutaneous tissue (sc). **b-** Mononuclear inflammatory cell aggregations and polymorph nuclear leucocytes (white arrow) with abundant newly formed blood capillaries (black arrows). H&E x100 and x200.



**Figure 6.** two weeks: **a-** more collagen fibers (black arrows) are present in the site with less inflammatory cellular reaction. **b-** The fibroblasts appeared to be in a close resemblance to the smooth muscle cells, and the newly formed blood capillaries (bc) still existed. H&E x300 and x200.



**Figure 7.** three weeks: **a-**The healed part (black arrows) appeared to be homogenous due to the presence of collagenous fibers which are closely intermingled and linked with the two sides. **b-** Inflammatory reaction still present manifested by the extended fibroblast cells to the subcutaneous tissue. H&E x100 and x200.

## Discussion

A skin flap is a partially detached segment of skin and subcutaneous tissue that includes a blood supply essential to its survival. As a result, skin flaps are capable of closing a variety of defects, including poorly vascularized wound beds that are incapable of healing otherwise. In many cases, skin flaps can overcome, economically, many of the potential problems associated with healing by second intention<sup>16</sup>. This skin flap technique can surpass some other reconstructive procedures such as skin grafting and skin expansion. It is stated that the acceptance of skin grafts in horses is unpredictable and the final cosmetic result can be disappointing<sup>17</sup>. Whereas, the biggest advantage of skin expansion is the spread of full-thickness skin over large defects in areas of high skin tension and where grafting techniques would not provide the same degree of protection<sup>14,15</sup>.

Both techniques can not be applied in the field and both require time either for the expansion of the skin or preparing the required graft of and both utilize more sophisticated equipments with unpredictable results. In contrary our technique is much more easy and applicable in the field. Wound shape was found to be of no significant effect on wound healing. It is reported that conversion of circular defects to square defects has no effect on wound healing<sup>18</sup>. All shapes of wounds showed proper healing within the first 10 days post-fixation.

Wound age was found to be of a critical importance. All experimental cases in this study were repaired within the first four hours of the experiment. It was more difficult to apply this constraint to the clinical cases. However, all clinical cases were operated within the first 9-12 hours. It is stated that the limit for an uncomplicated healing process lies around the first four hours<sup>19</sup>. Nevertheless, there was no significant delay in healing between the two groups. The success rate of the flap suturing was higher in the experimental groups (88.9%) rather than the clinical ones (78.6%). This could be mainly attributed to wound age and better wound management and of the experimental cases.

Flap size was smaller than the wound size. All skin flaps were reduced after incision and prior to fixation. In all of the cases, the skin flap size was smaller than wound size; this can be referred to the inciting trauma and tissue trimming. These findings agreed with those reported by Hudson-Peacock, et al.<sup>20</sup>. It was also suggested that the difference in flap/wound ratio is influenced by the age and by the lesion site and type<sup>20</sup>. To overcome the problem of flap shrinking, flaps were spread over the wound area. Then the flap tips, where the skin is maximally extensible, were sutured to the farthest point of the wound. This technique coincides with that described by Skiles, et al.<sup>21</sup>. Then other stitches were taken to apposition the flap to the wound lip.

The results of this study also demonstrated that there is a noticeable relationship between flap width and viable length. Skin flaps with length: width ratio of 3:1 failed in both experimental and clinical trials, yet those 2:1 were successful. These results confirm a previously unsupported assumption that flap width and viable length are related<sup>22</sup>. Others reported that the skin flap has a fixed survival rate regardless of the length of the flap<sup>23</sup>. The failed cases showed flap-tip necrosis, but the rest of the flap showed proper healing.

Wound repair is a complex series of coordinated events regulated by a delicately orchestrated cascade of cytokines and growth factors that restore the structural integrity of damaged tissue<sup>24</sup>. It is known that tissue repair requires a good blood supply and an adequate inflammatory response, which attracts macrophages and fibroblasts that are necessary for clearance of debris and initiation of repair. These cells are supported by the vascular endothelium<sup>25</sup>. Histologically, during the initial response to injury, platelet accumulation provided chemotactic attraction through platelet derived growth factor. At day 7 post-surgery, macrophages and other leukocytes were activated and infiltrated the wound. This initial inflammatory phase of wound healing included debridement of necrotic tissue and foreign debris and is crucial for initiation of the repair phase. Once this macrophage directed phagocytosis clears the tissue debris, perivascular pleuropotential mesenchymal cells differentiate into fibroblasts and myofibroblasts. These cells produced collagen, protein polysaccharide, and glycoprotein ground a process which reaches a peak around the fifth day after wounding<sup>26,27</sup>. The inflammatory response started to subside between day 7 and day 14. During the proliferative phase of wound healing rapid reduction in wound size was due to contraction of actin containing myofibroblasts<sup>28</sup>. A major challenge in reconstructive surgery is flap ischemia<sup>29</sup>. The applied new technique showed a rapid development of numerous new blood vessels at day 7 at the wound site which have intensely helped in the

survival of the skin flap. After 14 days, the healed part appeared to be homogenous due to the presence of collagenous fibers which are closely intermingled and linked with the two sides of the wound. With better understanding of equine wound and flap physiology, the outcome of treatments of difficult equine wounds should continue to improve. Although most equine wounds, including those with significant tissue loss, can be successfully managed, treated and heal without consequence, there are many that represent special challenges<sup>1,30</sup>.

In conclusion, the core of the described technique is to keep the flap in close apposition to the wound and cause immobilization of the flap/wound site for proper healing. The evenly distributed pressure all over the flap/wound surface helps in controlling hemorrhage and prevents gap formation under the flap which is important for the healing process. This technique can be considered as a rapid and successful field-application for the treatment of massive skin wounds in equine without the need of sophisticated equipments yet with good results.

## References

1. Hendrix SM, Baxter GM. Management of complicated wounds. *Vet Clin North Am Equine Pract* 2005;21:217-230.
2. Treat, L.A. Wire suturing technique for the repair of large wounds in horses. *Vet Med Small Anim Clin* 1969;64:76-77.
3. Roberts D. (1967): Velcro closure material in wound repair. *Vet Med Small Anim Clin* 1967;628:747.
4. Funkquist B, Obel N. Fixation of skin grafts in the horse using stainless steel staples. *Equine Vet J* 1979;11:117-121.
5. Schumacher J, Ford TS, Brumbaugh GW, et al. Viability of Split-Thickness Skin Grafts Attached with Fibrin Glue. *Can J Vet Res* 1996;158:158-160.
6. Twaddle AA. Rotation flap skin graft. *N Z Vet J* 1969;17:178-179.
7. Meagher DM, Adams OR. Skin transplantation in horses. *Can Vet J* 1970; 11:239-248.
8. Meagher DM, Adams OR. Split-thickness autologous skin transplantation in horses. *J Am Vet Med Assoc* 1971;159:55-60.
9. Hanselka DV. Use of autogenous meshgrafts in equine wound management. *J Am Vet Med Assoc* 1974;164:35-41.
10. Stashak TS. Reconstructive surgery in the horse. *J Am Vet Med Assoc* 1977;170:143-149.
11. Peyton LC. Reconstructive surgical techniques in the horse. *J Am Vet Med Assoc* 1981;179:460-463.
12. Bordet R. Skin grafts in equine and canine veterinary clinical practice. *Chirurgie* 1984; 110:391-394.
13. French DA, Fretz PB. Treatment of equine leg wounds using skin grafts: Thirty-five cases, 1975-1988. *Can Vet J* 1990;31:761-765.
14. Gomez JH, Schumacher J, Lauten SD, et al. Tissue expansion. *Vet Clin North Am Equine Pract* 1989;5:633-642.
15. Madison JB, Donawick WJ, Johnston DE, et al. The use of skin expansion to repair cosmetic defects in animals. *Vet Surg* 1989;181:15-21.
16. Hinchcliff KW, Macdonald DR, Lindsay WA. Pedicle skin flaps in ponies: viable length is related to flap width. *Equine Vet J* 1992;241:26-29.

17. Wilmink JM, van den Boom R, van Weeren PR, et al. The modified Meek technique as a novel method for skin grafting in horses: evaluation of acceptance, wound contraction and closure in chronic wounds. *Equine Vet J* 2006;38:324-329.
18. Madison JB, Gronwall RR. Influence of wound shape on wound contraction in horses. *Am J Vet Res* 1992;53:1575-1578.
19. Diehl M, Gerber H, Schifferli D, et al. Postoperative wound infection in the horse. *Tierarztl Prax Suppl* 1985;1:71-78.
20. Hudson-Peacock MJ, Matthews JNS, Lawrence CM. Relation between size of skin excision, wound, and specimen. *J Am Acad Dermatol* 1995;32:1010-1015.
21. Skiles MS, Chaglassian T. A simple geometric flap for the closure of skin defects. *Surg Gynecol Obstet* 1979;149:249-251.
22. Pavletic MM. Skin flaps in reconstructive surgery. *Vet Clin North Am Small Anim Pract* 1990;20:81-103.
23. Zhu B, Gao J, Hyakusoku H. Experimental study on the relationship between the ratio of pedicle width to flap width and the surviving length of the random skin flap. *J Plast Surg Burn* 1999 15:441-443.
24. Dart AJ, Dowling BA, Smith CL. Topical treatments in equine wound management. *Vet Clin North Am Equine Pract* 2005;21:77-89, vi-vii.
25. Silver I. Basic physiology of wound healing in the horse. *Equine Vet J* 1982;14:7-15.
26. Chvapil M, Holubec H, Chvapil T. Inert wound dressing is not desirable. *J Surg Res* 1991;51:245-252.
27. Stashak TS. *Equine wound management*. Pennsylvania: Lea&Febiger, 1991;11.
28. Wilmink JM, Stolk PW, van Weeren PR. Differences in second-intention wound healing between horses and ponies: macroscopic aspect. *Equine Vet J* 1999;31:53-60.
29. Zacchigna S, Papa G, Antonini A, et al. Improved Survival of Ischemic Cutaneous and Musculocutaneous Flaps after Vascular Endothelial Growth Factor Gene Transfer Using Adeno-Associated Virus Vectors. *Am J Pathol* 2005;167:981-991.
30. Bristol DG. Skin grafts and skin flaps in the horse. *Vet Clin North Am Equine Pract* 2005; 21:125-144.

## ارائه یک روش جدید در بازسازی زخم های وسیع و تازه با استفاده از آویخته های پوستی در اسب سانان

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**هدف-** ارائه یک روش جدید جهت بخیه زدن زخم های وسیع و تازه با استفاده از آویخته های پوستی در اسب سانان بدون توجه به جهت و یا موقعیت آویخته.

**طرح مطالعه-** مطالع تجربی در شرایط زنده و مطالعه میدانی.

**حیوانات-** ۹ رأس الاغ در مطالعات تجربی و ۲۸ رأس اسب با زخم های متفاوت از نظر شکل و موقعیت در مطالعات میدانی.

**روش کار-** کلیه زخم ها با استفاده از روش جدید تحت درمان قرار گرفتند. مدت زمان و میزان زنده بودن آویخته ها به مدت ۳ هفته از نظر بالینی با مشاهده وضعیت ظاهری و قوام پوست، رشد مو و روند التیام زخم و همچنین از نظر بافت شناسی با تهیه بیوپسی در روزهای ۷، ۱۴ و ۲۱ مورد بررسی قرار گرفت.

**نتایج-** التیام بسیار مطلوب زخم در تمامی موارد بالینی مشاهده گردید. از نظر بافت شناسی، همه آویخته ها التیام مناسبی را در روزهای ۷، ۱۴ و ۲۱ نشان دادند و در روز ۲۱ فضاهای زیرین توسط بافت طبیعی زیر پوستی پر شده بود.

**نتیجه گیری و کاربرد بالینی-** روش جدید، روشی سریع و موفق برای درمان زخم های وسیع و تازه با استفاده از آویخته های پوستی در اسب سانان بدون نیاز به ابزارهای پیچیده جراحی می باشد.

**کلید واژگان-** بازسازی زخم، آویخته های پوستی، اسب سانان.