Comparison of tensile strength and histopathological evaluation of wound healing process using adhesive skin tapes on laceration wounds of porcine skin

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Abstract. The procedures for closing a laceration wound vary. The efficacy of the new method using adhesive skin tape and its role in wound healing are unclear. Porcine skin is closely similar to human skin. This study was conducted on seven York Pork pigs in the laboratory of the Veterinary Teaching Hospital, Institut Pertanian, Bogor, Indonesia from August 2016 to September 2016. Three laceration wounds were made on the pig’s back and closed using skin suture (group 1), the recommended application (group 2), and a modified application (group 3). Histopathological evaluation was performed on days 7 and 30 by biopsy; tensile strength was evaluated after 6 weeks’ treatment. On day 7, there was a significant difference in the collagen deposition between groups 2 and 3, but there was no significant difference to group 1. There were no significant differences among the groups regarding subcutaneous fibroblasts and fibrocytes or tensile strength. The maximum force at rest was 380 ± 68.12 N. A modified application of adhesive skin tapes results in better collagen deposition and wound edge adaptation than the recommended application. However, the results of this method do not differ significantly from those of skin suture. Intradermal suture use increases tensile strength.

1. Introduction

Different physicians use varied procedures for closing a laceration wound. The choice of procedure depends on clinical judgment, the availability of suturing needs, and patient’s individual case and characteristics; the procedures still vary and are developing. The aim is to make the wound edges meet each other in eversion condition, so that the wound heals normally and leave a minimal scar [1].

There have been many studies on methods to reduce the possibilities of scarring and facilitate the normal wound healing process. Davis et al., in 2010, published a study that used a combination of sutures and 3M Steri-Strips to treat lacerations in thin-skinned individuals. This method is used to oppose the wound edges and hold them in place, prevent the sutures from cutting through the skin, and prevent shearing by transferring tension from the sutures to the 3M Steri-Strip on the epidermis to reduce morbidity [1].

Two different applications of adhesive skin tapes are used in daily clinical practice. The application recommended by the manufacturer is to space the tapes at an equal distance from each other. The
modified application is to overlap the adhesive skin tapes with each other. It is believed that the latter application will apply pressure to the wound edge, which will heal the wound properly and leave a minimal scar. Although the variances growth constantly, there have been no studies evaluating these applications in terms of histopathological signs of healing and tensile strength. These can be evaluated in an in vivo study or an animal study.

Dermatological research on wound healing, transdermal delivery, dermal toxicology, radiation, and ultraviolet B effects [2] has been performed in pigs, rats, rabbits, guinea pigs, and hairless rodents and on isolated parts of the animal body. Animals are chosen according to their physiological, biochemical, and anatomical similarity to humans [3]. Pig skin is closely similar to human skin [2]. A histopathological study that compared pig skin with human skin found similar antigens, including keratins 16 and 10, filagrin, collagen type IV, fibronectin, and vimentin [4].

The efficacy of the new method using adhesive skin tape and its role in wound healing are still unclear. It is thought that the use of adhesive skin tape will maintain the integrity of the epidermis, decrease tension, provide a partially closed environment, and improve the cosmetic outcome [5]. However, no study has investigated the role of adhesive skin tape in the wound healing process histologically or immunohistochemically or its tensile strength outcome clinically. We conducted such a study that compared the results of skin sutures, the recommended application of adhesive skin tapes, and a modified application of adhesive skin tapes in pigs.

2. Methods
2.1. Experimental animals
2.1.1. Procedure. Before the start of the study, the pigs underwent adaptation and a health test for 10 days. The pigs received antiparasitic treatment from the breeder before they were sent to the animal laboratory to ensure that they were free from endoparasites and ectoparasites. On the treatment day, the pigs were anesthetized with intramuscular ketamine and xylazine. After an anesthesia had been achieved, an intravenous line with Ringer’s lactate solution was inserted to maintain anesthesia.

The treatment was performed as follows. Initially, give an antiseptic at the back region of the pig. Then, three 10-cm incision lines spaced 5 cm apart were made on the back of the pig. A vasoconstrictor and an anesthetic using Pehacain along the lines was infiltrated, followed by a 7-minute wait for the drugs to have their effect. The incisions were then made with a no. 15 blade, cutting through the skin until the fat was reached. The laceration wounds were stitched with Vicryl 3.0 sutures cutting intradermally. Three different treatments were applied for the intradermally sutured wounds. In group 1, interrupted skin sutures were performed using Prolene 4.0 cutting on the sutured site. In group 2, 3M Steri-Strip adhesive skin tapes were placed on the sutured wound using the application recommended by the manufacturer. In group 3, 3M Steri-Strip adhesive skin tapes were placed on the sutured wound using the modified application. The laceration wounds were covered by gauze and then by a garment to keep the wound clean and prevent the tapes from detaching from the skin. A small hole was made in the garment over the urethra, so that the micturition process remains undisturbed.

After treatment, the pigs were given analgesics and antibiotics and were observed once daily by the attending veterinarian. On day 7 after treatment, the wounds were evaluated, and the skin sutures on the group 1 lacerations were removed. Then, punch biopsy specimens were obtained with an 8-mm diameter punch on the three laceration wounds to be examined in the pathology laboratory. Two slides were made for each tissue sample. One slide was stained with hematoxylin and eosin to evaluate the healing area of the laceration wound. The other slide was stained with Masson’s trichrome to evaluate the collagen deposition. The defects of the punch biopsies were closed with Prolene 2.0 cutting. The punch biopsy and staining procedures were repeated on day 30 after treatment to evaluate the collagen deposition and fibrotic changes.

The remaining sutured wounds were excised as far as the deep layer of fat 6 weeks after treatment. A pattern for each laceration wound was designed based on the pattern that was set and was suitable for
the tensile strength device in the Laboratory of Biomedical Technology, Faculty of Medicine, Universitas Indonesia. Each sample was examined for its tensile strength.

2.2. Assessment of research results
The results were assessed by microscopic evaluation. The slides were embedded in paraffin and the staining was conducted by the staff of the anatomy and pathology laboratory of the Faculty of Veterinary Medicine, Institut Pertanian Bogor (Bogor Agricultural University). The slides were stained with hematoxylin and eosin as well as Masson’s trichrome. The evaluations were conducted by the author in the pathology and anatomy laboratory of the Veterinary Teaching Hospital, Faculty of Veterinary Medicine, Bogor Agricultural University.

The slides were assessed for the collagen deposition and healing area on posttreatment days 7 and 30. The collagen deposition was evaluated on Masson’s trichrome-stained slides, on which the width of the collagen deposition between the wound edges on the dermis was identified. The healing area was assessed on hematoxylin and eosin-stained slides; the size of the area with fibroblasts and fibrocytes in the subcutaneous layer above the superficial fat was identified. Both evaluations used a microscope with a 4× objective lens and 10× ocular lens, and the images were measured with a standardized bar using ImageJ software.

After all the tissue samples had been obtained, the tensile strength of the skin was measured with an Instron Application Device at the Biomedical Technology Laboratory, Faculty of Medicine, Universitas Indonesia.

2.3. Statistical analysis
For all measurements, the data were tested for normal distribution by the Shapiro–Wilk test and were analyzed using one-way analysis of variance (ANOVA).

3. Results
3.1. Descriptive data of subjects
All subjects got through all the research protocols except subject A, who became sick after the treatment and received medication from the attending veterinarian. The biopsy had to be performed on day 7 after treatment based on the protocol. The subject could not tolerate the anesthetic effect and died the day after the biopsy. Data on the sex and weight of the subjects are summarized in Table 1.

| Subject | Sex | Weight on admission (kg) | Weight on treatment day (kg) | Weight on day 7 (kg) | Weight on day 30 (kg) |
|---------|-----|-------------------------|-----------------------------|---------------------|---------------------|
| A       | Male| 21                      | 21                          | 20                  | Died                |
| B       | Male| 31                      | 33                          | 31                  | 35                  |
| C       | Male| 25                      | 26                          | 26                  | 33                  |
| D       | Male| 24                      | 24                          | 26                  | 28                  |
| E       | Male| 26                      | 26                          | 27                  | 34                  |
| F       | Female| 21                     | 22                          | 23                  | 25                  |
| G       | Male| 25                      | 26                          | 26                  | 29                  |
| Mean    |     | 24.71                   | 25.43                       | 25.57               | 30.67               |
The data were tested for normality by the Shapiro–Wilk test and found that all the data for weight were normally distributed. The mean weight increased from the day of admission to day 30.

3.2. Collagen deposition
The collagen deposition was evaluated on Masson's trichrome-stained slides, which showed the width of the collagen deposition between the wound edges in the dermis. Figure 1 shows the results of the evaluation performed on day 7 after treatment. The data for all groups on day 7 were normally distributed according to the Shapiro–Wilk test.

![Figure 1. Evaluation of biopsy slide from day 7 with Masson’s trichrome staining. (A) Histopathological figure for group 1 of subject F. (B) Histopathological figure for group 2 of subject C. (C) Histopathological figure for group 3 of subject D.](image1)

The data on the collagen deposition for day 7 were analyzed using one-way ANOVA. There was a significant difference between groups 2 and 3 ($p = 0.026$), but there were no significant differences among the other groups (Table 2).

|        | Group 1 | Group 2 | Group 3 |
|--------|---------|---------|---------|
| Group 1|         | 0.150   | 1.000   |
| Group 2| 0.150   |         | 0.026   |
| Group 3| 1.000   | 0.026   |         |

![Figure 2. Evaluation of biopsy slide from day 30 with Masson’s trichrome staining. (A) Histopathological figure for group 1 of subject C. (B) Histopathological figure for group 2 of subject D. (C) Histopathological figure for group 3 of subject E.](image2)
Analysis of the data on collagen deposition for day 30, which were performed using one-way ANOVA, found no significant differences among the three groups (Table 3).

**Table 3.** *p*-values for comparison of collagen deposition on day 30.

|       | Group 1 | Group 2 | Group 3 |
|-------|---------|---------|---------|
| Group 1 | -       | 0.37    | 1.000   |
| Group 2 | 0.370   | -       | 0.205   |
| Group 3 | 1.000   | 0.205   | -       |

3.3. Healing area
The healing area was assessed on hematoxylin and eosin-stained slides, on which the size of the subcutaneous area with fibroblasts and fibrocytes just above the superficial fat was identified. Figure 3 shows the evaluation on day 7 after treatment. The data for all groups on day 7 were normally distributed according to the Shapiro–Wilk test.

**Figure 3.** Evaluation of biopsy slide from day 7 with hematoxylin and eosin staining. (A) Histopathological figure for group 1 of subject G. (B) Histopathological figure for group 2 of subject C. (C) Histopathological figure for group 3 of subject F.

Analysis of the data on healing area from day 7, which was performed using one-way ANOVA, showed significant differences among all groups (Table 4).

**Table 4.** *p*-values for comparison of healing areas on day 7.

|       | Group 1 | Group 2 | Group 3 |
|-------|---------|---------|---------|
| Group 1 | -       | 0.133   | 0.974   |
| Group 2 | 0.133   | -       | 0.794   |
| Group 3 | 0.974   | 0.794   | -       |

Figure 4 shows the evaluation of biopsy slides on day 30 after treatment. The data for all groups on day 30 were normally distributed according to the Shapiro–Wilk test.
Figure 4. Evaluation of biopsy slide from day 30 with hematoxylin and eosin staining. (A) Histopathological figure for group 1 of subject C. (B) Histopathological figure for group 2 of subject F. (C) Histopathological figure for group 3 of subject E.

Analysis of the data on the healing area for day 30 performed using one-way ANOVA found no significant differences among the three groups (Table 5).

Table 5. p-values for comparison of healing areas on day 30.

|       | Group 1 | Group 2 | Group 3 |
|-------|---------|---------|---------|
| Group 1 | -       | 1.000   | 0.991   |
| Group 2 | 1.000   | -       | 1.000   |
| Group 3 | 0.991   | 1.000   | -       |

3.4. Tensile strength

Analysis of the data on tensile strength, which used one-way ANOVA, found no significant differences among the three groups (Table 6).

Table 6. p-values for comparison of tensile strength.

|       | Group 1 | Group 2 | Group 3 |
|-------|---------|---------|---------|
| Group 1 | -       | 1.000   | 0.992   |
| Group 2 | 1.000   | -       | 0.897   |
| Group 3 | 0.992   | 0.897   | -       |

4. Discussion

The behavior of the pig is difficult to control when the healing process produces sensations such as an itchy feeling on the wound. This can make the pig rub its back on the cage bar, resulting in detachment of the tape. This possibility was eliminated using a garment to keep the tapes attached to the wound. The tapes were attached to the pig’s skin until day 7 after treatment, as the skin sutures were kept on the wounds of pigs in group 1.

Six of the seven pigs in this study were male. The weights of the pigs increased during the study, indicating that their nutrition was good and the healing process was not hindered by nutritional problems.
On day 7, there was a significant difference in the collagen deposition between groups 2 and 3, but there were no significant differences among the other groups. The width of the collagen deposition was the narrowest in group 3, which means that the adaptation of the wound edge was good (31.99 ± 9.97 mm). This result shows that the modified application is superior to the recommended application, and, therefore, the surgeon could get a better result with the modified application. However, the collagen deposition did not significantly differ between groups 1 and 3; therefore, both methods still give good results in wound healing.

Conversely, the condition changes due to the healing process. On day 30 after treatment, there were no significant differences among the groups in the collagen deposition. In this case, the skin tapes or skin sutures held the wound edges, but after they were removed, the intradermal sutures still held the wound until they were totally absorbed.

According to the results of the hematoxylin and eosin-stained slides, there were no significant differences among the three groups in fibroblasts and fibrocytes in the subcutaneous layer just above the superficial fat on days 7 and 30 after treatment. It caused by the same treatment for the intradermal suture that was given before application of skin sutures or skin tapes. The absorbable thread that is used for intradermal sutures provokes a reaction in the dermis, so that the deposition of fibroblasts and fibrocytes in the healing area is the same for all groups [6]. When nonabsorbable threads or skin tapes are used, there are no fibroblasts or fibrocytes in reaction to the skin sutures [7].

There were no significant differences among the groups in measurements of tensile strength. The maximum force at the rest was 380 ± 68.12 N. This means that there was no difference between the adaptation of the wound edges by skin sutures and skin tapes. This may be because the intradermal sutures that are applied to the wound provide major strength to the wound until they are absorbed and the wound is healed. This condition may be useful in cases where skin sutures should be avoided, such as laceration wounds in children, when the removal of the stitches is difficult when the patient is awake or when skin suturing is difficult in an unconscious patient [7].

5. Conclusion
The modified application of adhesive skin tapes provides better collagen deposition and wound edge adaptation than the recommended application. However, the results of the modified application of adhesive skin tapes do not significantly differ from those of skin sutures. The intradermal suture has a major role in providing tensile strength to wound healing, and it does not depend on what is applied to the superficial part of the skin because it will be removed in a short period of time.

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