Application of Sweet Potato Fiber to Skin Wound in Rat

Toshio Suzuki,‡ Hitoshi Tada, Etsuko Sato, and Yoshinori Sagae

Department of Pharmaceutical Science, Akita University Hospital, 1–1–1 Hondo, Akita 010, Japan.

Received November 1, 1995; accepted April 17, 1996

In order to introduce a suitable drug mixing base or covering for burns or decubital wounds, the usefulness of fiber extracted from the sweet potato was investigated. The healing effect of the fiber was evaluated by examining the extent of reduction in the size of wounds and changes in the quality of wounds in rats. In contrast to the control, the use of the fiber alone as a wound covering material reduced wounded areas by 21.0% at postoperative day 9, 19.5% at day 11, and 18.7% at day 13, and resulted in an obvious increase in the rats' weight. The number of days required for healing in all treated rats was 19 for the fiber groups and over 21 d for the control. In vitro, the fiber indicated excellent absorptive ability for serum and good adhesive ability for a number of proteins. This result suggested that the fiber has favorable properties for healing wounds which contain large amounts of exudate. Our macroscopic findings also indicated that the fiber protected wounds from dryness. These results suggested that sweet potato fiber could be use as a covering material in combination with drugs in skin wound therapy.

Key words dietary fiber; sweet potato fiber; dressing; wound; burn; rat

In wound therapy, dextranomer has been used to absorb exudate and necrotic tissue.1) Sucrose possesses wound debridement and has a granulation effect.2) These drug mixing bases are combined with iodines to create a superior drug for wounds, and also act as an antiseptic.3,4) However, many wound drugs are prepared as ointments which are not suitable for absorbing exudate and necrotic tissue. Therefore, it is anticipated that the development of a drug mixing base which is able to overcome these defects would further accelerate the healing process of wounds.

Although many studies concerning dietary fiber have been reported with the objective of management of constipation,3) the treatment of ulcer disease4,5) and or the prevention of hyperlipemia,6–9) the utility of the fiber as a drug preparation or dressing for wounds has never been investigated and its effect is uncertain.

The present study was conducted to investigate the use of sweet potato fiber as a drug preparation or dressing for wounds. We prepared several experimental drugs for combined use with the fiber and applied them to experimental wounds in rat and then evaluated the role of sweet potato fiber based on the results of the healing rate and quality of wounds treated with the experimental and commercially available preparations.

MATERIALS AND METHODS

Chemicals Satsumaimo fiber® (sweet potato fiber) was supplied by Kyushyukako Co., Ltd. (Kagoshima, Japan) and consists of water (87.9%), protein (0%), fat (0.4%), ash (1.0%) and carbohydrate (10.7%). The total energy is 46 kcal/100 g. The carbohydrate includes cellulose (7.62%). Povidone-iodine was provided by Meiji Seika Co., Ltd. (Tokyo, Japan). Tretinoin tocoferil and Olcenon® ointment were provided by Lederle (Japan) Co., Ltd. (Tokyo, Japan) and the latter contains 0.25% of tretinoin tocoferil in the ointment base. Shiun-kou® is an herbal preparation whose principal component is acetylshikonin.11) Shiun-kou® was obtained from Tsumura Co., Ltd. (Tokyo, Japan). U-Pasta® was provided by Kowa Co., Ltd. (Nagoya, Japan) and sucrose (70.0 g), povidone-iodine (3.0 g), and water (27.0 g) are contained in this preparation (100 g). Cadex® was supplied by Nihon Iyakukin Kogyo Co., Ltd. (Toyama, Japan), and both dextranomer/cadexomer (991 mg) and iodine (9 mg) are contained in this preparation (1 g). Bradykinin, prostaglandin E2 (PGE2), γ-globulin and fibrinogen were obtained from Sigma Chemical Co., Ltd. (St. Louis, U.S.A.). Bovine serum albumin was obtained from Wako Pure Chemicals (Osaka, Japan). All other chemicals used in this experiment were commercial products.

Purification of Sweet Potato Fiber Successive washing of Satsumaimo fiber with absolute ethanol (1000 ml) and ether was followed by drying in vacuo to provide a sweet potato fiber (172.8 g, weight recovery 17.2%). It was used into this work after powdering with tablet crusher.

Preparation of Povidone-Iodine, Tretinoin Tocopheril and Shiun-kou Fiber To prepare the povidone-iodine fiber, povidone-iodine (270 mg) was added to the fiber (30 g) and it was dried with stirring in a dark place at room temperature. A solution of each drug, tretinoin tocoferil (75 mg) or Shiun-kou® (30 g), in ether (30 ml) was added to the fiber (30 g) and the mixtures were stirred for 10 min. The solvent was evaporated and the residue was dried at room temperature to afford the corresponding tretinoin tocoferil fiber and shiun-kou fiber.

Absorptive Ability of the Fiber Preparations to Serum Fiber (0.5 g) was wrapped with a tea bag (95 mm × 70 mm, Marusan Sangyou Co., Ltd., Ehime, Japan) and it was soaked in human serum (10 ml) for 3 min. After the tea bag was pulled up, dripping serum from tea bag was wiped by paper and the fiber was weighed. Its absorptive ability was represented as a weight titer of serum contained per the fiber preparation.

Adhesive Ability of the Fiber to γ-Globulin, Fibrinogen, PGE2, and Bradykinin in vitro 0.1 M phosphate buffer solution (pH 7.4, 1 ml) containing γ-globulin (3 mg/ml) or fibrinogen (3 mg/ml) was added to the sweet potato fiber (100 mg) and it was shaken violently for 3 min and centrifuged at 1600 × g. The γ-globulin or fibrinogen content in the supernatant was determined as the bovine

© 1996 Pharmaceutical Society of Japan
serum albumin concentration according to the procedure of Lowry et al. To test the adhesive ability of cholesterol to the fiber, human male serum (1 ml) was mixed with the fiber (100 mg) and it was then shaken violently for 3 min and thereafter centrifuged at 1600 × g for 10 min. The cholesterol concentration in the supernatant was measured by a Determiner-TC555 kit (Kyowa Medix Co., Ltd., Tokyo, Japan). To examine the adhesive ability of PGE2 to the fiber, PGE2 (1 mg) was dissolved into 0.05 M phosphate buffer solution (pH 6.8) containing 0.9% NaCl, 0.01 M EDTA, 0.3% bovine γ-globulin, 0.005% Triton X-100 and 0.05% sodium azide, and the PGE2 concentration was diluted to 20 pg/ml with the buffer. The solution (5 ml) was added to the fiber (500 mg), it was then shaken violently for 3 min and centrifuged at 1600 × g for 10 min. Measurement of the PGE2 level in serum was performed using the assay of Kawano et al. To test the adhesive ability of bradykinin to the fiber, physiological saline containing bradykinin (100 pg/ml) was used as a sample. The solution (5 ml) was violently shaken with the fiber (500 mg) for 3 min, and centrifuged at 1600 × g for 10 min. The bradykinin content in the supernatant was determined according to the method of Ando et al.

Preparation of Open Wound Model in Rat  Male Wistar rats (215—245 g) were anesthetized with pentobarbital (i.p., 40 mg/kg) following an overnight fast, and the hair on the back was removed carefully with an animal clipper and an electronic shaver. After disinfecting the back with 70% alcohol, an iron stick (12 mm i.d.) with a thermo-controlled device set at 200°C was pressed at two sites: 30 mm toward the tail from the shoulder and 10 mm right and left from the median line for 20 s to prepare third degree burns on the right and left sides of the rats' backs. The left side was treated only with sterilized gauze (control) and the right side was treated with an experimental drug. The rat was anesthetized with pentobarbital (i.p., 32 mg/kg) 2 d after the burn preparation and the necrotic tissue was surgically excised. In order to protect the open wound from the rat's own physical stimulus, the wound was covered with sterilized gauze which was secured with surgical tape until the silicon plates were set.

Application of Experimental Drugs to Wound in Rat  Five rats were used in each group and they were under pentobarbital anesthesia during application of the experimental drugs. A 5 mm thick and 25 × 25 mm silicon plate with a hole (14 mm in diameter) in the center was secured to the rat's wound with an instantaneous adhesive agent. The experimental drug was put in the hole of the silicon plate to come into contact with the wound site. The dose of the experimental drug was set as follows: The dose of the drug containing iodine was equivalent to the active iodine content (1.8 mg) when the hole of the silicon plate was filled with povidone-iodine fiber. In practice, povidone-iodine fiber, Cadex® and U-Pasta® (600 mg) were used. The doses of other experimental drugs were equivalent to the volume of the hole of the silicon plate. In practice, Olecon® ointment (800 mg), Shiun-kou® (250 mg) and other fiber preparations (250 mg) were used. Cadex® and U-Pasta® were used as positive controls for povidone-iodine fiber. Olecon® and Shiun-kou® were also used as controls, for tretonin, tocopheril fiber and shiun-kou fiber, respectively. The experimental drugs were covered with gauze to prevent the mixtures from leaking out of the hole, and the silicon board was secured to the rat's body with a hypoallergenic adhesive bandage. Tested drugs were applied from the day after the operation and were changed every day for a week after the operation and every other day for 7 to 21 d after the operation. The site of the wound was traced on a transparent glass plate with a felt tipped marker and further traced on tracing paper. Tracing paper corresponding to the area of the wound was cut precisely and the area of the wound was calculated by the weight of the tracing paper. In order to prevent infection, the wound site was washed with sterilized saline and 0.5% (v/v) chlorhexidine gluconate solution before and after the application of experimental drugs and measurement of the area of the wound.

The protocols for animal experiments were previously approved by the Animal Research Committee, Akita University School of Medicine; all subsequent animal experiments adhered to the Guidelines for Animal Experimentation of the University.

Rat Weight after Excision  We measured the body weight of the rats in each drug-treatment group and control group was treated only with gauze on both sides, and in the healthy group which did not receive the burns or operation.

Histological Processing  Male Wistar rats (220—240 g) were anesthetized with pentobarbital (i.p. 40 mg/kg) and the burn wound was prepared with the excision of necrotic tissue after burn damage (200°C, 20 s). The wound was treated with the fiber or gauze for 13 d after the operation. The wound sites were isolated under anesthesia with pentobarbital (i.p., 40 mg/kg) and specimens were fixed with 10% neutral formalin fluid and processed on a paraffin section. They were stained with hematoxylin-eosin or azan. The epidermic healing was evaluated microscopically using an Olympus BH-2 microscope (Tokyo, Japan).

Statistical Analysis  Statistical evaluation was performed by one-way analysis of variance supplemented with the multiple comparison procedure of Tukey in the YUKMS program (YUKMS Co., Ltd., Tokyo), and a p value of < 0.05 was considered to be statistically significant.

RESULTS

Adhesive Ability of the Fiber in Relation to γ-Globulin, Fibrinogen, PGE2 and Bradykinin in Vitro  The ability of the fiber preparations to absorb serum is shown in Table 1. Fiber alone demonstrated the largest absorptive ability among the fiber preparations. The fiber (1 g) was able to absorb 4.6 ml of serum, the same amount absorbed by Cadex®. In comparison with the absorptive ability of fiber alone, the absorptive ability of Shiun-kou® and of the other fiber preparations in which other drugs were added was 50% or less.

Table 2 presents the adhesive ability of the fiber with a dolorogenic substance and protein in inflammatory injuries. Almost the same adhesive ability was observed in γ-globulin and fibrinogen, but not in PGE2.

Healing Rate of Wound in Rat  The percentage change
in the area of the experimental wound after the operation is illustrated in Fig. 1. The reducing effect of the fiber alone was excellent when compared with that of the control and other experimental drugs. The most pronounced differences were observed at 9, 11 and 13 d after operation: the fiber reduced the area of the wound more than 18% in contrast to the control each time, a significant difference. Although wounds treated with shiun-kou fiber and povidone-iodine fiber indicated a tendency to shrink, a significant difference from the control was not observed. However, wound areas treated with povidone-iodine fiber showed the greatest reduction after those treated with fiber alone on the 13th postoperative day, and a marked difference was seen compared to the reduction resulting from treatment with U-Pasta®, which also contained povidone-iodine. Cadex® and Olenon® ointment and tretinoin tocoferil fiber tended to show delayed healing rates in the experimental drugs in which they were used. The data on shiun-kou® cannot be presented in Fig. 1 due to the deaths of 60% of the animals during the experiment.

Rat Weight after Excision Figure 2 indicates the weight changes in the rats after the operation. Although weight loss was observed in animals treated with most preparations at postoperative days 1 to 3, the weights in the fiber alone and shiun-kou fiber groups increased or were unchanged. Only the weights of the group treated with fiber alone showed a notable increase among the groups treated with experimental drugs. In contrast, the weights of rats treated with tretinoin tocoferil fiber and shiun-kou fiber at postoperative day 13 exceeded the weights measured on the operative day.

Histological Findings in the Fiber The histological findings of wounds treated with fiber alone are represented in Figs. 3 and 4. Although node formations in connective tissues were found in the control, they were not recognized in the fiber groups. And although the normal epithelialization that progressed in the fiber groups was clearly distinct from the disorderly epithelialization and node formation in the control, there were no observed differences in the number of fibroblast cells between the fiber groups and the control in this study.

Required Days for Healing The numbers of days required for healing are shown in Table 3. All of the wounds were healed in the fiber and povidone-iodine fiber groups at postoperative day 19. Healing in the shiun-kou fiber group and Olenon® ointment group was delayed for an additional two days. Healing in rats treated with other preparations, including the control, required more than 21 d after the excision.

Macroscopic Findings At postoperative day 7, a reddening of the wound was found in the group treated

---

Table 1. Mean Absorptive Ability of Several Preparations for Human Serum

<table>
<thead>
<tr>
<th>Preparations</th>
<th>Ability (Titer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>4.6</td>
</tr>
<tr>
<td>Povidone-iodine fiber</td>
<td>3.6</td>
</tr>
<tr>
<td>Tretinoin tocoferil fiber</td>
<td>4.2</td>
</tr>
<tr>
<td>Shiun-kou fiber</td>
<td>2.0</td>
</tr>
<tr>
<td>Cadex®</td>
<td>4.6</td>
</tr>
</tbody>
</table>

a) The value was obtained from the duplication.

Table 2. Mean Adhesive Ability of the Fiber for Several Physiological Agents

<table>
<thead>
<tr>
<th>Physiological agent</th>
<th>Adhesion (mg) per 1 g of the fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>γ-Globulins</td>
<td>14.7</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>15.3</td>
</tr>
<tr>
<td>Bradykinin</td>
<td>$344 \times 10^{-9}$</td>
</tr>
<tr>
<td>PGE₂</td>
<td>Not adhered</td>
</tr>
</tbody>
</table>

a) The value was obtained from the duplication.

---

Fig. 1. Time Courses of Wound Area after Excision of Necrotized Skin in Rat Back (Mean ± S.E., n = 3–5)

Each paragraph shows the relative ratio of the wound areas which were measured the next day after excision of the necrotized skin induced by burn. a) Significantly different at p < 0.01. b) Significantly different at p < 0.05. Key: ■, fiber (n = 5); □, povidone-iodine fiber (n = 5); ●, U-Pasta® (n = 5); ○, Cadex® (n = 3); ◆, shiun-kou fiber (n = 4); ◇, tretinoin tocoferil fiber (n = 4); ◇, Olenon® ointment (n = 3); □, control (n = 29).
with fiber alone, and some necrotic tissue was found covering the center of the wound, and the fiber was wet on the part coming into contact with the wound. The povidone-iodine fiber preparation was as wet as the fiber preparation and the color of the iodine was faded. A little bleeding was observed in the wound and the drug was melted by exudate in the U-Pasta® group. There was neither bleeding nor necrotic tissue in the Cadex® group, though a reddening of the wound was found. Cadexomer on the wound was bleached and expanded by the absorption of a large amount of exudate. In the tretinoin tocoferil fiber and shiun-kou fiber groups, the colors were not faded, regardless of wetting. In the Shiun-kou® group, a lot of necrotic tissue and bleeding were found in the surrounding wound, a large amount of exudate flowed out from the wound, and the raggedness of the wound was remarkably increased compared with the shiun-kou fiber group. Necrotic tissue, exudate and bleeding were found to the same extent in the Shiun-kou® group as in the control.

At postoperative day 11, necrotic tissue partially remained in the dressing of the group treated with fiber alone and sometimes the fiber was stuck to the skin where bleeding occurred. Povidone-iodine fiber coming into contact with the wound contained exudate, and this resulted in the release of povidone-iodine from the preparation. U-Pasta® covered the wound like a syrup. With Cadex®, cadexomer was bleached on the part coming into contact with the wound and was expanded. Bleeding was observed in the tretinoin tocoferil fiber group. The necrotic tissue around the wound treated with shiun-kou fiber was less than that induced by the control and neither exudate nor bleeding could be seen in the shiun-kou fiber. However, necrotic tissue, a large amount of exudate, and bleeding were found in the animals which were treated with Shuon-kou® alone, as was the case with the control.

At postoperative day 15, wounds were almost completely healed in the fiber and povidone-iodine fiber groups, and were covered in part with a scab. In the U-Pasta® group, the syrup and scab covered the wound surface. Reddening of the wound site and slight bleeding in addition to scab formations were observed in the Cadex® group. None of the wounds were cured in the tretinoin tocoferil fiber, Olenen® ointment, shiun-kou fiber or Shiuon-kou® groups. In the control, exudate and reddening were observed in part, though necrotic tissue

Fig. 2. Time Courses of Mean Body Weight after Excision of Nocrotized Skin in Rat Back (n=3–5)

Key: ■ fiber (n=5); ● povidone-iodine fiber (n=5); ○, U-Pasta® (n=5); □, Cadex® (n=3); △, shiun-kou fiber (n=4); ▪, tretinoin tocoferil fiber (n=4); O, Olenen® ointment (n=3); ○, healthy rat (n=5); ○, non-treatment (n=5). a, i Fiber vs. non-treatment. b, j Povidone-iodine fiber vs. non-treatment. c, k Healthy rat vs. non-treatment. d, l, U-Pasta® vs. non-treatment. e, m Shiuon-kou fiber vs. non-treatment. f, n Cadex® vs. non-treatment. g, o Olenen® ointment vs. non-treatment. h, p Tretinoin tocoferil fiber vs. non-treatment. a–h) Significant difference was observed between them at p<0.05. i–p) Significant difference was observed between them at p<0.01.

Fig. 3. Histological Feature of the Middle Part of the Wound at 13d after Treatment with Fiber Alone (a) and Using Sterilized Gauze (b)

a: Though the center of the wound had not been covered with the epidermis, the expansion of the epidermis was observed at the periphery of the wound. However, the connective tissues were exposed so there is a large amount of infiltration of erythrocytes and new vessels were regenerated under the surface of the wound. b: The reproduced epidermis was still not observed in the center of the wound. The connective tissue was exposed on the entire surface of the wound. a, b: scale bar = 800 µm, azan stain.
action of the fiber. It was predicted that a combination of the water absorptive fiber with an antimicrobial agent or a drug to accelerate tissue repair would bring us closer to a more ideal preparation for the treatment of skin ulcers. Based on this prediction, fiber preparations containing povidone-iodine, with its disinfecting effect, and tretinoin tcoferil, with its tissue-repairing action, were prepared respectively. Shiun-kou® has been widely used as a herbal preparation for burns in Japan. Since lard is used as a base in Shiun-kou®, it cannot be expected to absorb, so the only drawback of this drug is that it cannot be used for the initial inflammation stage of a burn. In order to overcome this drawback, shiun-kou fiber was prepared. As found in Table 1, although the fiber alone (1 g) could absorb 4.6 ml of serum, this absorptive ability was decreased to 2.0 ml when mixed with Shiun-kou®. This decrease in absorptive ability was also observed in other experimental preparations. Serum was used as a substitute for exudate in this study. The decrease in absorptive capacity due to the addition of drugs must be considered when new fiber preparations are developed in the future. Our present results indicated that the fiber could absorb some proteins such as fibrinogen or γ-globulin (Table 2). Since these results suggested that the fiber has useful characteristics for removing necrotic tissue, we expected the use of the fiber to demonstrate some advantages in the inhibition of scab production.

Bradykinin and PGE$_2$, are known to exist and to induce pain in wounds. We performed adsorption tests using typical pain producing substances to examine the usefulness of the fiber in reducing pain in skin ulcers. As a result, the amount of bradykinin absorbed by the fiber was 344 pg per 1 g of the fiber, corresponding to 13.7 ml of whole blood based on a report by Scicli et al. This suggested the possibility that the fiber is useful for reducing pain.

Since Himann et al. first advocated the concept of moist wound healing in 1963, a number of authors have reported that the epidermis is more rapidly regenerated in a moist condition. In our study, though necrotic tissue was present in wounds treated with the fiber and povidone-iodine fiber, scabs and bleeding were not observed, as opposed to the control. Moreover, the surface of the wounds was moist on the 11th and the 13th day after starting the treatment when almost no effusion was found. This shows that the fiber not only absorbs exudate, but also prevents the wounds from drying. The fiber can absorb effusion in a moist condition, though it has no antimicrobial activity. So, the fiber is thought to absorb under a condition similar to that recommended by Himann et al. and Breuing. These findings seemed to indicate that the fiber should not be classified as a dry dressing.

Although there tended to be less necrotic tissue in the group treated with fiber alone than in the control, it was not less than that in the Cadex® group. These findings seemed to reflect the protein absorption effect confirmed in vitro, but the effect was not as potent as that exhibited by the Cadex® group. It cannot be denied, however, that an excessively potent protein absorption effect entails the risk of the absorption of materials in the periphery of a wound needed for the regeneration of the epidermis. This

Table 3. Days Required to Heal All of Wound

<table>
<thead>
<tr>
<th>Preparation</th>
<th>Days after operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>19</td>
</tr>
<tr>
<td>Povidone-iodine fiber</td>
<td>19</td>
</tr>
<tr>
<td>U-Pasta®</td>
<td>≥21</td>
</tr>
<tr>
<td>Cadex®</td>
<td>≥21</td>
</tr>
<tr>
<td>Shiun-kou fiber</td>
<td>21</td>
</tr>
<tr>
<td>Tretinoin tcoferil fiber</td>
<td>≥21</td>
</tr>
<tr>
<td>Ocleon® ointment</td>
<td>21</td>
</tr>
<tr>
<td>Control</td>
<td>&gt;21</td>
</tr>
</tbody>
</table>

was not noticed.

At postoperative day 21, all cases were healed in the fiber, povidone-iodine fiber, shiun-kou fiber, and Ocleon® ointment groups. However, the wound was still covered with a scab in the U-Pasta®, Cadex®, and tretinoin tcoferil fiber groups. In the control, the wound, in which reddening remained, was covered with a scab.

DISCUSSION

In in vitro experiments to investigate the effective use of sweet potato fiber, we found a strong water absorptive

![Image](image_url)
appeared to cause the delay in healing that is observed in the Cadex® group, as shown in Fig. 1. On the other hand, in the control, a widening of necrotic tissue was observed in the peripheral tissue. In addition, the failure to absorb due to the presence of too much exudate was found for several days following the operation. Bleeding due to the separation of the epidermis occurred when the gauze was changed. In contrast, in the fiber treatment groups, the fiber which attached to the epithelium could be left in place during the exchange, and it was possible to avoid separation of the epithelium and the associated bleeding.

In order to study the influence of experimental drugs on total body condition in rats, we monitored changes in body weight as an index. There was a significant difference in the weight gain in the group treated with fiber alone, and the number of days required for complete healing was small in contrast to that for control (Fig. 2, Table 3). This result may be a reflection of both the extent and the quality of wound healing. In fact, a few days after the operation, apparent findings such as bleeding and amounts of exudate were smaller in the fiber groups than in the others, and the removal of exudate was sufficient in the fiber alone group. Therefore, it is valid to suggest that there is a possibility that invasive stresses, including pain, were restrained by covering the wound with the fiber. To cite one example, the adhesive ability in the fiber for bradykinin, as shown in Table 2, may also be instrumental in the decrease of pain.

Although iodine was released from the part absorbing the exudate in the povidone-iodine fiber group, the healing speed and rate of weight increase were slightly slower than in the fiber-alone group. In order to explain this, it is necessary to consider that in addition to the tissue-damaging side effect caused by the presence of povidone-iodine itself,22) the use of povidone-iodine also leads to a decrease in the ability of the fiber to absorb exudate. However, none of the animals treated with povidone-iodine fiber died. Furthermore, animals in this group developed a larger reduction in size of the wound and a more pronounced increase in body weight compared to animals in groups which were treated with other drugs (Figs. 1 and 2). Therefore, it is thought that the use of a disinfectant fiber preparation like povidone-iodine fiber is clinically rational. However, we could not determine to what extent the disinfection effect of povidone-iodine contributed to those results, because decubitus ulcers appear easily on old and other patients whose defense mechanism toward bacteria is weakened.

Although the therapeutic effect of fiber is also made evident by the different survival numbers of the shiun-kou fiber and Shiu-kou® groups, the healing rate in the Olcenon® ointment group was almost the same as that of the control group, while the tretinoin tocoferol fiber group tended to show a delayed healing rate compared with the control (Fig. 1). Though the stimulation of cell migration23) and an increase in the number of human skin fibroblasts24) are recognized as effects of tretinoin tocoferol and the granulation effect25) is found in Shiu-kou®, in general, they must be applied after inflammation subsides,26) because neither preparation absorbs exudate well. It was assumed that beginning the application of the preparations the day after an operation, as in our protocol, would result in undesirable effects such as the propagation of bacteria. U-Pasta® also did not show a sufficient healing effect because it was dissolved by large amounts of exudate. With shiun-kou fiber and tretinoin tocoferol fiber, the ability to absorb exudate was weakened because of the clearance in the fiber molecule chain which was covered or filled up with an added drug or a base with weak polarity. It seems that the fiber could not make sufficient use of its inherent merits due to these factors.

The purpose of our experiment was to mix the fiber and preparations, such as ointment, which ordinarily do not exudate well for use in the early stage of inflammation. Improvement of the absorptive ability of both mixtures was confirmed in vitro when fiber was combined with tretinoin tocoferol and Shiu-kou® (Table 1). The addition of fiber to tretinoin tocoferol did not show a favorable influence, though the advantage of the fiber is recognized in other preparations (Macroscopic findings and Fig. 1). The ratio of fiber to tretinoin tocoferol may not have been appropriate because only one mixing ratio was prepared in this study. It was thought that suitable individual ratios must be reexamined in further studies, taking into consideration the characteristics of the materials and effect of each drug.

From histological findings at 13 d postoperation, many node formations with connective tissues were observed in the control (Fig. 3). The expansion of the regenerative epidermis in the nodal parts was disturbed, and this may be one cause of the delay in healing. Epithelialization is known to start when the granulation tissue totally fills the defect. In this study, there was no difference in the number of fibroblast cells between the fiber group and the control. A detailed study of the relation between fibroblasts and treatment with fiber may be necessary.

A key requisite for a drug preparation or dressing is that it should not be decomposed by bacteria. Considering the purification method of the raw material, cellulose is thought to be the main component of the fiber. Further studies are needed to clarify whether the fiber is easily decomposed by bacteria and whether its physicochemical characteristics are maintained after long-term use.

Our experiment suggested that sweet potato fiber helps wounds heal by absorbing exudate and necrotic tissue while at the same time preventing bacterial infection with the formation of a barrier and by keeping humidity on the wound. In addition, a drug which does not disturb the absorptive potential of the fiber should be used. It may be necessary to examine the presence of antigenicity by comparing it with dressings such as hydrocolloid,27–36) though no allergic symptoms were observed in rats in this study as a result of the fiber.

In conclusion, our findings strongly suggest that sweet potato fiber could be a favorable mixing base for combination with drugs or as a dressing in wound therapy.

**Acknowledgments** The authors would like to thank Drs. Kohichi Kawamura, and Tatsuroh Sugiyama for helpful discussions on histological analysis. We also thank Mr. Takuya Sato for skillful technical assistance.
REFERENCES