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Original Article

Clinical observation of elastic skin stretch combined with perforator flap for wound repair

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Abstract: Objective: To investigate the clinical effect of elastic skin stretch combined with perforator flap in the treatment of extremity wound defects. Methods: The clinical data of 42 patients with extremity wound defects were retrospectively compared and analyzed. Among them, 26 patients (observation group) were treated with elastic skin stretch combined with perforator flap, while 16 patients (control group) were treated with autologous free skin graft or flap transplantation for wound closure. The hospital stay, postoperative wound healing, and wound operation times were compared and analyzed, and the satisfaction rate of the patients was investigated. At the same time, the shallow bleeding point, hemodynamics and diameter of perforating artery of the patients in the observation group were measured with high frequency ultrasound, and the correlation between them and skin flap survival was analyzed. Results: The hospital stay in the observation group was significantly shorter than that in the control group ($P<0.05$). There was no significant difference in postoperative infection rate and wound operation times between the two groups ($P>0.05$). The patients in the observation group showed significantly higher satisfaction rate than those in the control group ($P<0.05$). In the observation group, the blood flow at shallow bleeding point, diameter and velocity of perforating artery on the 1st, 3rd, 5th and 7th day after surgery were higher than those before surgery (all $P<0.05$). The blood flow at shallow bleeding point in flap survival group was higher than that in flap necrosis group ($P<0.05$), while there was no significant difference in diameter or velocity between the two groups (all $P>0.05$). The survival of the flap was positively correlated with the blood flow at penetrating point ($P<0.05$), but was not correlated with the diameter and the velocity of the perforating artery ($P>0.05$). Conclusion: Elastic skin stretch combined with perforator flap promotes the rehabilitation and improves the satisfaction of patients in the treatment of extremity wound defects. Moreover, the survival rate of perforator flap is closely related to the blood flow of perforating artery.

Keywords: Elastic skin stretch, perforator flap, extremity wound defects, wound repair

Introduction

Extremity wound defects, common in clinic, are mostly caused by burns, trauma and surgery. With the development of social modernization and transportation, the number of trauma patients, especially those with extremity wound defects, has been increasing. It is difficult to repair extremity wound defects caused by trauma because they are often accompanied by exposure of deep tissues such as bones, tendons and nerves, with multiple injuries, and large, irregular-shaped wounds [1, 2]. In clinic, skin graft is commonly used to restore the integrity, function and appearance of the wounded skin, but it may lead to infection of donor site, poor abrasion resistance of skin, skin graft contracture and scar hyperplasia [3]. According to related research, the incidence of complications in the treatment of extremity wound defects by skin graft alone hits 26.67%, not to mention the obviously prolonged healing time and hospital stay [4]. Therefore, better treatments of extremity wound defects have long been explored clinically. The elasticity and extensibility of skin is the premise of skin stretching and remodeling, making it possible for external forces to promote the formation and repair of skin tissue [5]. An animal experiment has shown that skin stretcher combined with Kirschner wire is not only superior to direct suture in repairing skin defect (5 × 5 cm), but also has little side effect on skin histology and microcirculation [6].

Recent years have witnessed the application of perforator flap and elastic skin stretch to wound defect treatment. In elastic skin stretch, skin-

stretching device is applied to stretch the skin around the wound to gradually cover the wound, so as to promote wound closure [7, 8]. Therefore, skin graft can be avoided [9]. In perforator flap, a certain size of flap from other parts of the patients is transplanted to cover the wound. Because the flap has good blood supply, it improves the blood supply of the wound and enhances the repairing quality. Related studies have shown that in treating the patients with extremity wound defects, fascia pedicle flap transplantation (34.38%) showed the higher incidence of distal extremity swelling than pedicled perforator flaps (10.26%) [10, 11]. On one hand, due to the slow closure of the wound during the elastic skin stretch, the wound is prone to infection after long-term exposure. On the other hand, repair with perforator flap has a risk of flap necrosis. Therefore, combining elastic skin stretch and perforator flap can complement each other and make up the shortcomings in the treatment of extremity wound defects, which is conducive to promoting the rehabilitation of patients. However, there are currently no clinical reports on the combined application of elastic skin stretch and perforator flap. Therefore, this study retrospectively analyzed 42 patients with extremity wound defects and observed the application value of elastic skin stretch and perforator flap.

Materials and methods

General data

The data of 42 patients with extremity wound defects admitted to The First Affiliated Hospital of Bengbu Medical College from January 2015 to January 2018 were retrospectively compared and analyzed. Among them, 26 patients (observation group) were treated with elastic skin stretch combined with perforator flap, while 16 patients (control group) were treated with traditional therapy. All patients and their families were informed and signed informed consent forms. Inclusion criteria: Patients with skin and soft tissue defects caused by trauma; patients aged 18-65 years; patients with defects caused by extremity open wounds; patients with wound that cannot be spontaneously healed or be sutured directly. Exclusion criteria: patients complicated with vascular occlusive disease, malignant tumor, or factors causing wound dehiscence, such as diabetes, smoking, anemia, poor nutritional status, etc. This study was approved by the Medical Ethics Committee of The First Affiliated Hospital of Bengbu Medical College.

Methods

After routine disinfection and draping, necrotic tissue, blood clots, and foreign bodies were removed from fresh open wound to repair damaged blood vessels, while only necrotic tissue was removed from delayed healing wound followed by routine cleaning. On this basis, the observation group used elastic skin stretch and perforator flap to repair the wound. Elastic skin stretch: according to the shape of the wound, the direction of the needling was selected, which was oriented to the long axis of the wound as far as possible. One osseous pin (1.5-3 cm, Zimmer, USA) pricked the skin at 0.5-1.5 cm from the wound edge and was driven in the junction of dermis and subcutaneous tissue, then driven out after approximately 2-3 cm horizontal movement. Afterwards, the pin pricked the skin again at a distance of 2-3 cm from the exit point, and then was driven out at a distance of 2-3 cm. The process was repeated until the pin was driven out through 1 cm from the distal edge of the wound. The opposite side was also operated in the same way. A skin stretcher (Beijing Institute of External Skeletal Fixation Technology) with appropriate tension for skin and adaptation to skin wound was selected. The stretcher nut was moderately adjusted to keep the skin expanded to a certain extent. The expansion trend, color changes and bleeding of the stretched skin were observed. When the distance between the wound edges was less than 10 mm, the stretcher was removed and the wound was sutured intermittently. Repair with flaps: according to the size of skin and soft tissue defect, the thoracodorsal flap was taken for repair. Free circumflex scapular and subscapular vessels were harvested along the thoracodorsal vessel. Attention was paid to protect the perforating vessel from 15 cm below the axillary margin to 2 cm behind the anterior edge of latissimus dorsi. Flap with perforating vessel was obtained with the vascular pedicle protected. The flap was cut into about 30 mm × 60 mm in the largest area and 10 mm × 18 mm in the smallest area size. After confirming the normal blood supply of the flap, the pedicle was cut off to make it in a “T” shape. The donor area was sutured. The perforator flap was used to cover the wound. The posterior tibial vessel on the tendinous side was cut off. The vascular pedicle was anastomosed with the severed artery and vein vessels respective-

ly. Skin graft was performed on the surface of the vascular pedicle. The pedicle was divided 7-8 days after surgery for 2-3 hours. If the blood supply of the flap remained normal, the pedicle could be completely divided.

The control group was treated by traditional methods: autologous free skin graft or flap transplantation was used for wound closure. Repair with flap: the flap was cut off; the donor area was sutured; the distal end of main trunk of the vascular pedicle was ligated; and the blood supply was observed after the anastomosis of the flap. Autologous free skin graft: a split-thickness skin slice larger than about 10% of the wound on the ipsilateral side or tendinous side was trimmed, sutured and fixed to cover the wound. According to the bacterial culture results, the wounds in the two groups were treated with sensitive antibiotics, including carbapenems and β-lactamase. Measurement of the defect size: a 1-yuan coin was placed beside the wound, a camera (Canon, Japanese, IXUS860IS) was applied to photograph the wound, and the photo was uploaded to Photoshop to measure the size.

Outcome measures

All the patients with extremity wound defects were treated with flap repairing in The First Affiliated Hospital of Bengbu Medical College. Their case files were established immediately after admission, and the complete clinical data were available. They had a return visit six months after discharge and were followed up by special personnel.

The hospital stay, postoperative infection, wound operation times and satisfaction rate were compared between the two groups. Satisfaction rate: the survey included the operation effect, appearance and function. Satisfactory: survival of flap or skin graft; normal appearance with no scar hyperplasia, depression or pigmentation; recovery of normal sensory function. Basically satisfactory: partial survival of flap or skin graft; basically normal appearance with mild scar hyperplasia and pigmentation; reduced sensation compared with tendon y side. Unsatisfactory: necrosis flap or skin graft in need of secondary operation; obvious scar hyperplasia, depression and pigmentation; no feeling or numbness. Satisfactory rate = (Total number of cases-number of unsatisfactory cases)/total number of cases × 100%. Definition of flap or skin graft survival: flap or skin graft firmly adhered to the wound, and skin temperature was normal or 2-3°C lower than that of the tendon side; no inflammatory reaction occurred on the defect area, and no infection on adjacent tissues; the defect area showed ruddy and glossy in color, and the skin returned to normal within 2 seconds after pressing, with no swelling. Definition of flap or skin graft necrosis: 24 hours after surgery, the skin turned pale or blue asphyxia, with blisters on the surface; then the necrotic area gradually darkened, hardened and fell off. In the observation group, a high frequency ultrasound (Siemens, German ultrasound diagnostic system ACUSON P500) was used to measure the blood flow at shallow bleeding point, as well as the hemodynamics and diameter of perforating artery.

Statistical analysis

SPSS19.0 statistical software was used for statistical analysis. The measurement data were expressed by mean ± standard deviation ($\bar{x}$ ± sd). The paired t test was used for intra-group comparison and the independent t test was used for inter-group comparison. The counting data were expressed by number/percentage (n/%) and analyzed by χ^2 test. The Spearman rank correlation was employed to analyze the correlation between the blood flow at shallow bleeding point, diameter, velocity of perforating artery and flap survival. A value of $P<0.05$ was considered statistically significant.

Results

General data

There was no statistical difference between the two groups in gender, average age, defect size and number of cases of concurrent infection (all P>0.05), indicating a comparability. See **Table 1**.

Comparison of hospital stay, postoperative infection and wound operation times

The hospital stay in the observation group was significantly shorter than that in the control group (P<0.05). There was no significant difference in wound operation times and the postoperative infection rate between the two groups (both P>0.05). See **Table 2** and **Figure 1**.

Comparison of satisfaction rate

The total satisfaction rate in the observation group (96.15%) was significantly higher than

Table 1. Comparison of general information ($\bar{x}$ ± sd, n)

Group	Observation group (n=26)	Control group (n=16)	χ^2/t	P
Gender (n)			0.303	0.582
Male	14	10		
Female	12	6		
Average age (year)	36.79±4.88	37.12±5.14	0.209	0.836
Area of skin defect (cm^2)	80.23±12.52	82.37±13.08	0.530	0.600
Concurrent infection (n)	8	5	0.097	0.974
Malnutrition (n)	7	4	0.050	0.891
Injured part (n)			0.404	0.525
Upper limb	12	9		
Lower limbs	14	7		
Body mass index (kg/m^2)	28.75±2.87	28.63±3.02	0.129	0.898
Cause of injury (n)			1.565	0.457
Explosive injury	8	3		
Traffic accident injury	16	10		
Wring injury	2	3		

Table 2. Comparison of hospital stay, postoperative infection and wound operation times ($\bar{x}$ ± sd, n (%))

Group	Observation group (n=26)	Control group (n=16)	χ^2/t	P
Hospital stay (h)	62.38±10.45	85.61±15.37	5.838	0.000
Postoperative infection	2 (7.69)	1 (6.25)	0.194	0.860
Wound operation times (time)	2.86±1.12	3.04±1.25	0.484	0.631

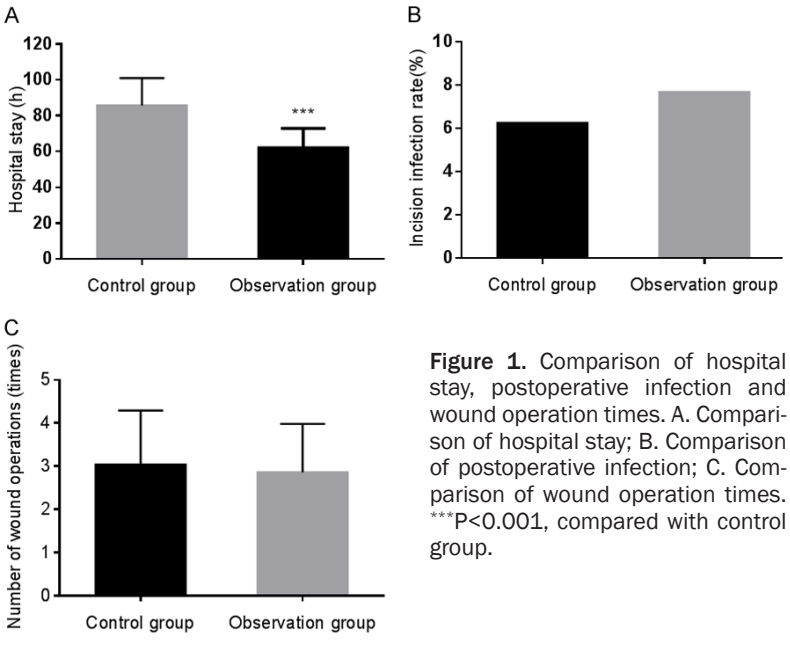

Figure 1. Comparison of hospital stay, postoperative infection and wound operation times. A. Comparison of hospital stay; B. Comparison of postoperative infection; C. Comparison of wound operation times. ***P<0.001, compared with control group.

that in the control group (62.50%; P<0.05). See **Table 3**.

Comparison of blood flow at shallow bleeding point, diameter, and velocity of perforating artery before and after surgery

In the observation group, the blood flow at shallow bleeding point, diameter and velocity of perforating artery increased gradually after surgery, reaching the peak on the 5th day, and then decreased gradually. The indexes on the 1st, 3rd, 5th and 7th day after surgery were higher than those before surgery (all P<0.05). See **Table 4** and **Figure 2**.

Comparison of blood flow at shallow bleeding point, diameter, and velocity of perforating artery between surviving and necrotic flaps

Of the 26 patients in the observation group, there were 21 cases of surviving flaps and 5 of necrotic flaps. The blood flow at shallow bleeding point in the flap survival group was higher than that in the flap necrosis group. There was no significant difference between the two groups in diameter and velocity of perforating artery (both P>0.05). See **Table 5** and **Figure 3**.

The correlation between blood flow at shallow bleeding point, diameter, velocity of perforating artery and flap survival

The flap survival was positively correlated with the blood flow at the shallow bleeding point of perforating artery (P<0.05), but was not correlated with the diameter and the velocity of the perforating artery (both P>0.05). See **Table 6**.

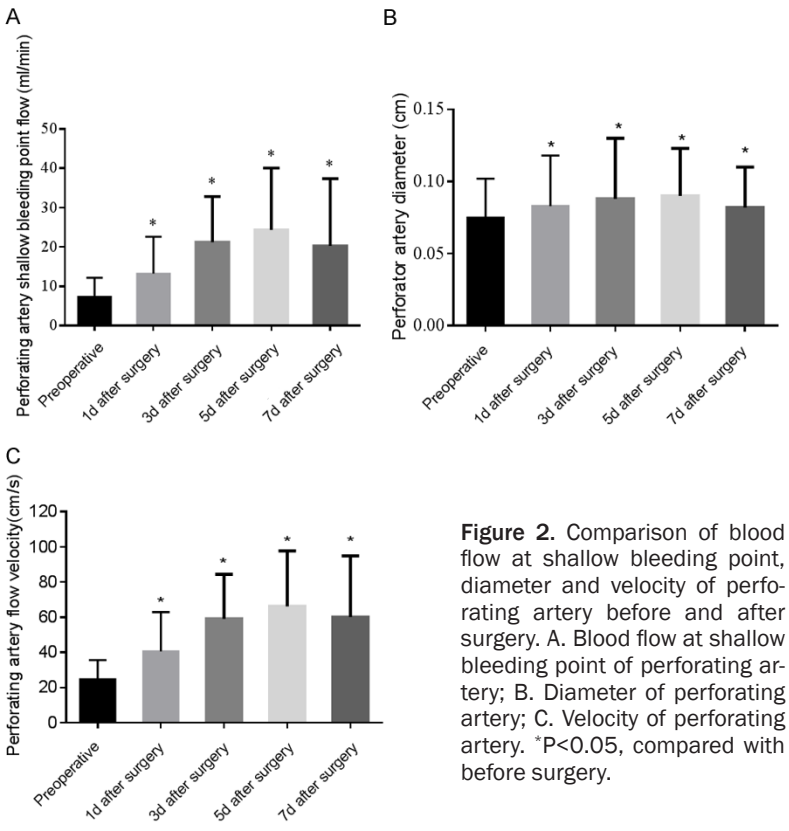

Figure 2. Comparison of blood flow at shallow bleeding point, diameter and velocity of perforating artery before and after surgery. A. Blood flow at shallow bleeding point of perforating artery; B. Diameter of perforating artery; C. Velocity of perforating artery. *P<0.05, compared with before surgery.

Table 3. Comparison of satisfaction rate (n, %)

Group	Observation group (n=26)	Control group (n=16)	χ^2	P
Satisfactory	13 (50.00)	3 (18.75)		
Basically satisfactory	12 (46.15)	7 (43.75)		
Unsatisfactory	1 (3.85)	6 (37.50)		
Total satisfactory rate (%)	25 (96.15)	10 (62.50)	5.836	0.005

Table 4. Comparison of blood flow at shallow bleeding point, diameter, and velocity of perforating artery before and after surgery ($\overline{x}$ ± sd)

Group	Blood flow at shallow bleeding point (mL/min)	Diameter of perforating artery (cm)	Velocity of perforating artery (cm/s)
Before surgery	7.33±4.85	0.075±0.027	24.74±10.87
1 d after surgery	13.24±9.36*	0.083±0.035*	40.65±22.32*
3 d after surgery	21.23±11.58*	0.088±0.042*	59.12±25.35*
5 d after surgery	24.36±15.71*	0.090±0.033*	66.29±31.45*
7 d after surgery	20.27±17.09*	0.082±0.028*	60.19±34.76*

Note: *P<0.05, compared with before surgery.

Discussion

In this study, patients in the observation group were treated with elastic skin stretch combined with perforator flap to repair extremity wound defects, whose hospital stay was significantly shortened compared with that in the control group. Wound repair with perforator flap is mainly carried out by selecting an appropriate donor site and cutting the skin flap with the same size as the wound for transplantation, which has advantages of wide donor site, high selectivity, and simple operation, in addition to relatively constant blood vessels and simple preparation of sensate flap [12-14]. It is applicable to large, deep wounds with bone defects or tendon injuries [15-18].

However, flap necrosis may occur in wound repair with perforator flap [8]. Elastic skin stretch utilizes the elasticity and extensibility of skin to slowly cover and gradually close the wound by applying external force to healthy skin around the wound, thus repairing the defect area. Clinical research shows that compared with the patients with skin and soft tissue defects treated with non-skin stretch, those treated with skin stretch showed a significantly shorter hospital stay [19]. However, the expansion of skin may affect the blood supply of the surrounding tissues, and excessive expansion speed or range may cause ischemia and necrosis of the skin and the pressed parts [20]. Therefore, combination of elastic skin stretch and perforator flap has the potential of synergizing and complementing each other, thereby promoting wound recovery. In this study, benefiting from the combination of elastic skin stretch and perforator flap, patients with extrem-

Table 5. Comparison of blood flow at shallow bleeding point, diameter and velocity of perforating artery between flap survival group and flap necrosis group ($\bar{x}$ ± sd)

Group	Blood flow at shallow bleeding point (mL/min)	Diameter of perforating artery (cm)	Velocity of perforating artery (cm/s)
Flap survival group (n=21)	25.46±10.69	0.086±0.037	56.63±30.27
Flap necrosis group (n=5)	15.14±4.64	0.084±0.032	52.46±31.41
t	2.086	0.111	0.253
P	0.048	0.913	0.804

Table 6. The correlation between blood flow at shallow bleeding point, diameter, velocity of perforating artery and flap survival

Variable	Flap survival	
	r	P
Blood flow at shallow bleeding point of perforating artery	3.752	0.004
Diameter of perforating artery	1.028	0.371
Velocity of perforating artery	1.155	0.286

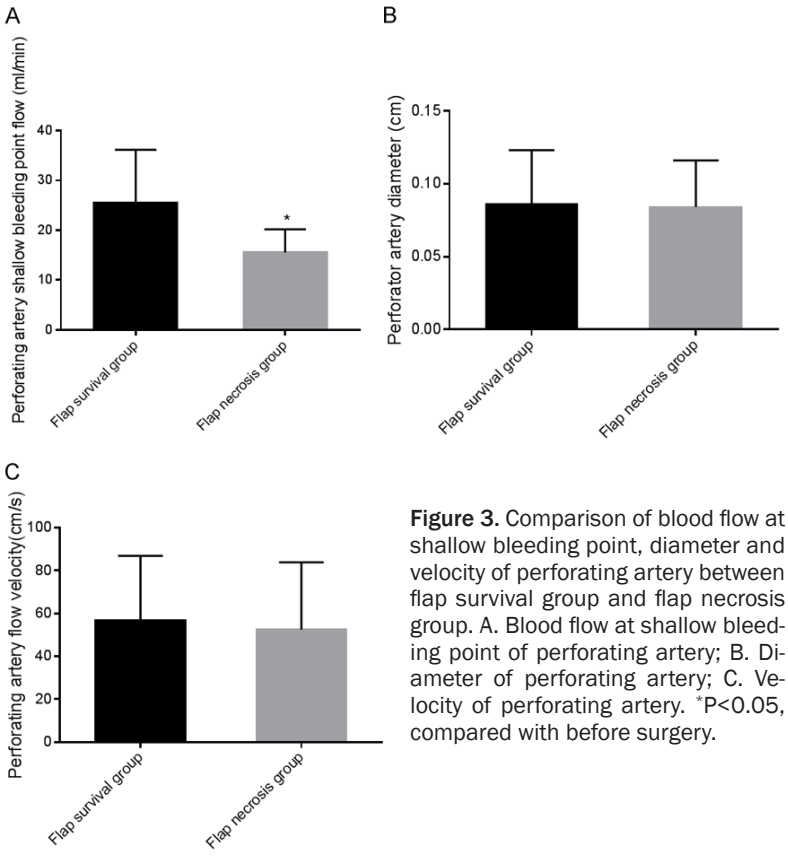

Figure 3. Comparison of blood flow at shallow bleeding point, diameter and velocity of perforating artery between flap survival group and flap necrosis group. A. Blood flow at shallow bleeding point of perforating artery; B. Diameter of perforating artery; C. Velocity of perforating artery. *P<0.05, compared with before surgery.

ity wound defects got a faster recovery and shorter hospital stay.

At the same time, due to the influence of flap size, postoperative wound infection, and blood circulation of the flap, there is a 13.7% risk of flap necrosis when the perforator flap is applied for wound repair [20]. Zhu et al. retrospectively analyzed 78 cases of failed flap transplantation from January 2010 to January 2018 [21]. The results revealed that flap necrosis is prone to occur 1 week after surgery, and infection was the main reason to blame. Repair surgery operated by professional microsurgery doctors was more conducive to reducing the necrosis rate. In this study, ultrasound examination of the perforator flap in the observation group showed that the blood flow at shallow bleeding point of perforating artery in the flap survival group was higher than that in the flap necrosis group, while there was no significant difference in diameter and velocity between the two groups. Further correlation analysis demonstrated that flap survival was positively correlated with the blood flow at shallow bleeding point, but was not correlated with the diameter and the velocity of the perforating artery. It may be because that the blood flow at shallow bleeding point of perforating artery directly affects the blood supply of the flap. As a result, higher blood flow leads to better blood supply and is more beneficial to the flap survival. Conversely, it easily leads to insufficient blood supply, poor local blood supply and necrosis of the flap.

Our study showed that elastic skin stretch and perforator flap shortened the hospital stay and improved patient satisfaction in the treatment of extremity wound defects. Moreover, the survival rate of perforator flap was closely related

to the blood flow of perforating artery. However, due to the small sample size and limited evidence, it is necessary to expand the sample size for further confirmation. In addition, applied in repairing large soft tissue defect infections of limbs and other parts, the feasibility of elastic skin stretch combined with perforator flap still needs to be discussed.

To sum up, the elastic skin stretch combined with perforator flap is effective in the treatment of extremity wound defects. Moreover, it can promote the rapid healing of skin wounds, with simple operation and high safety. Therefore, it is worthy of promotion and application.

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Disclosure of conflict of interest

None.

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