

A prospective analysis of the efficacy of phase II autologous skin grafting on deep second-degree burns on the dorsum of the hand

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Abstract. The aim of the present study was to investigate the possibility of reducing the damage to the donor site while preserving the functional recovery of the dorsum of the hand following burn injury. An attempt was made to analyze the effect of a phased surgery approach on inflammatory indicators. A two-phase treatment was administered on a total of 64 patients with deep second-degree burns on the dorsum of the hand who were admitted to Guangzhou Red Cross Hospital between January 2020 and March 2023. During phase I treatment, the wounds were covered with xenogeneic (porcine) skin, followed by the application of autologous thin intermediate thickness skin grafts for wound repair in phase II treatment 1 week later. The surgical results, complications, patient satisfaction and inflammatory response indicators were then analyzed. The mean wound healing time of these patients was found to be 21.94 days without complications. The mean survival rate was 98.66%, and the overall satisfaction score of the patients was high. Finally, the white blood cell, C-reactive protein and IL-6 levels of these patients were continuously decreased 2 days preoperatively and 2 days postoperatively in phase I, and 2 days preoperatively and 2 days postoperatively in phase II. In combination, the effect of phased autologous skin grafting in patients

with severe second-degree burns on the dorsum of the hand was ideal, as it significantly reduced inflammatory response and was beneficial to the functional recovery of the hand. Therefore, phased autologous skin grafting is worthy of wider application.

Introduction

Following a burn, the skin loses its defensive capacity, which predisposes it to infection and a series of complications, such as burn sepsis and bacteremia, thus increasing the mortality rate of patients (1). At present, with the development of science and technology, an increasing number of treatment methods are available for burns. Currently, the main treatment modality is the application of autologous skin grafting. However, the healing of split-thickness skin grafts (STSGs) following burn injury is often accompanied by scar growth, leading to joint contracture deformities and significantly affecting hand function (2). The present study observed that after early allograft or xenograft coverage in patients with large surface area deep second-degree burns on the dorsum of the hand, thin intermediate thickness skin grafts (ITSGs), rather than full thickness skin grafts (FTSGs), were used to repair the wounds, due to the lack of skin source (3). In patients who adhered to anti-scarring therapy and functional exercises, no significant limitation of hand function was observed during the long-term follow-ups (4). The misjudgment of tissue health status and the residual of necrotic tissue in early stage surgical treatment would directly affect the survival of skin grafts (5,6). Thus, phased surgery circumvents those problems, further improves functional reconstruction of the hand following burns and increases the survival rate of skin grafts. The present study attempted to determine the impact of phased skin graft repair of wounds on patients with burns. Due to the variation in damage to the donor area caused by the use of skin grafts of varying thickness, the possibility of reducing the damage to the donor site while preserving the functional recovery of the dorsum of the hand was investigated. The present study also attempted to analyze the effect of phased surgery on inflammatory indicators. Patients with deep second-degree burns and indications for skin grafting surgery were selected for the present study. As some third-degree burns of the hand may be

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accompanied by exposed bone and tendons, flap transfer repair is often required to ensure function recovery. The survival rate of ITSGs over burn wounds was lower compared with that of STSGs. Thin ITSGs on patients with deep second-degree burns on the dorsum of the hand can improve the survival rate, reduce damage to the donor area (7,8) and cause no significant functional limitations following wound healing with anti-scar therapy and exercise (9). In the present study, 64 patients with deep second-degree burns on the dorsum of the hand admitted to Guangzhou Red Cross Hospital between January 2020 and March 2023 were enrolled, and the safety and effectiveness of covering with allogeneic (porcine) skin in phase I and then transplantation of autologous thin ITSGs in phase II were analyzed.

Materials and methods

Patients. A total of 64 patients with dorsal hand burns admitted to Guangzhou Red Cross Hospital (Guangzhou, China) between January 2020 and March 2023 were enrolled in the present study. This study complied with the ethical guidelines of the Declaration of Helsinki and was approved by the Clinical Ethics Committee of Guangzhou Red Cross Hospital (Guangzhou, China; approval no. 2021-153-01). All enrolled patients provided written informed consent. The inclusion criteria were as follows: i) Complete data; ii) diagnostic criteria for deep second-degree burns of the dorsal hand with clear surgical indications; iii) first surgery at the trauma location, admitted to the unit within 7 days from injury; iv) high compliance and normal cognitive function; v) $2\% \leq \text{burn area} \leq 10\%$; vi) young-adult males aged 18–45 years (mean age, 33.1 ± 2.4 years). The exclusion criteria were as follows: i) Abnormal coagulation; ii) liver and kidney dysfunction; iii) malignant tumors; iv) ulcers or severe infection symptoms at the burn site; v) no third-degree burn trauma.

Methods. One week after the patients' injury, the allogeneic (porcine) skin [artificial skin-genetically transfected porcine skin (skin patch)] was used to cover the trauma during phase I treatment. The allogeneic (porcine) skin was thawed and washed repeatedly, and small holes were poked in it for drainage; the necrotic scab on the back of the hand was excised and treated with adequate hemostasis, followed by repeated rinsing with 0.5% povidone iodine (PVP-I) and saline successively. After checking that there was no active bleeding, the xenograft (pig) skin was implanted according to the wound shape, and the edges were sutured and fixed with finger compression dressing and immobilization. Postoperative anti-infection treatment was provided, and the phase II surgery was performed 7 days after the completion of the phase I surgery. The suture at the edge of the xenograft (porcine) skin was removed, the xenograft was carefully separated to avoid tearing the newly formed granulation tissue. Careful observation was made to check for any remaining necrotic tissue or residual xenograft. The wound surface was lightly scraped to induce slight bleeding, followed by repeated rinsing with 0.5% PVP-I and normal saline. Once there was no active bleeding, the size of the dorsal hand wound was measured, and a large thin ITSGs (~0.45 mm thick) was harvested from the anterior lateral aspect of the contralateral thigh. The graft was implanted according to the

shape of the wound, and the edges were sutured for fixation. Finger compression on dressing and immobilization, as well as postoperative anti-infection treatment, were performed. The dressings were removed after 7 days.

Observation indices. The wound healing time was calculated from the beginning of the post-injury period. 7-day survival and infection rates following phase II skin grafting: The survival rate was calculated as a percentage of the grafting area, with no dressing change considered as 100% survival. The complications were as follows: i) Infection rate on the first dressing removal for trauma culture after stage II surgery, with the detection of bacteria or fungi considered as 100% infection; ii) displacement of skin pieces: Comparison of intra-operative grafts appeared to be displaced; iii) subcutaneous blood accumulation: Incomplete hemostasis or uneven pressure led to subcutaneous blood accumulation, followed by skin piece inactivation; iv) inflammatory index: Fasting venous blood was taken 2 days before and after phase I surgery, and 2 days before and after phase II surgery, and the levels of white blood cell (WBC), C-reactive protein (CRP) and IL-6 were measured. v) Vancouver Scar Scale (VSS) at the 6-month post-operative follow-up, where 0–5 was considered significantly effective, 6–10 effective and 11–15 ineffective [the effective rate = (the number of significant cases + the number of effective cases) / total cases $\times 100$] (10). vi) At the 6-month postoperative follow-up, the satisfaction questionnaire was used to assess patient satisfaction: >85 points, very satisfied; 65–85 points, satisfied; <65 points, unsatisfied [satisfaction = number of (very satisfied + satisfied) cases / total number of cases $\times 100$] (11).

Statistical analysis. Data were processed using SPSS 24.0 statistical software (IBM Corp.). ANOVA with repeated measures was used for comparisons among multiple time points, and Bonferroni's post-hoc test was used for post-hoc test. $P < 0.05$ was considered to indicate a statistically significant difference.

Results

Wound healing time. The mean healing time was 21.94 days, with 23 cases undergoing phase I surgery 7 days after injury, 21 cases undergoing phase I surgery 8 days after injury, 16 cases undergoing phase I surgery 9 days after injury, 2 cases undergoing phase I surgery 10 days after injury, 1 case undergoing phase I surgery 11 days after injury, and 1 case undergoing phase I surgery 12 days after injury. The patients who underwent surgery 10–12 days after injury were all transferred to the Guangzhou Red Cross Hospital 5–7 days after injury, and the remaining patients were admitted to the Guangzhou Red Cross Hospital immediately after injury or within 2 days from injury.

Complication rate, treatment effect and patient satisfaction. The survival rate of all 64 surgical patients was >95%, with a survival rate of 98.66%, and no patients presented with skin fragment displacement, pressure inactivation or infection. According to the VSS, 44 cases were considered significantly effective (score, 0–5), 19 cases were considered effective (score, 6–10), and 1 case was considered ineffective

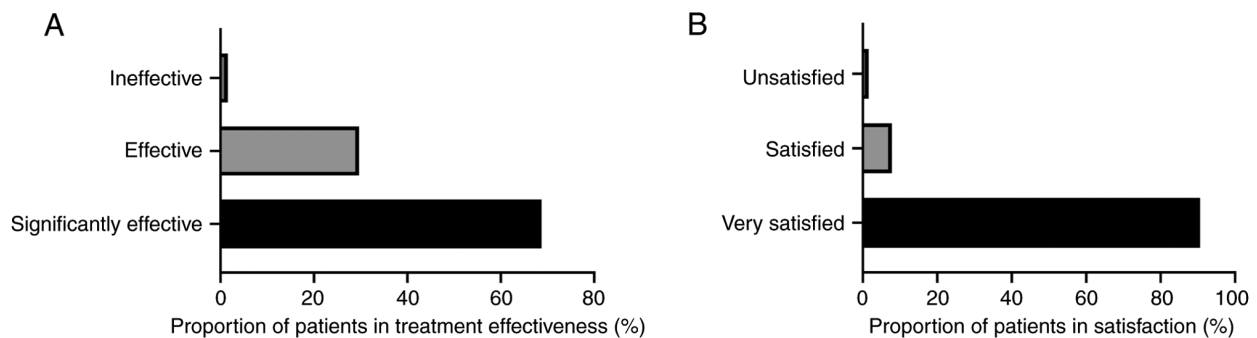


Figure 1. Follow-up Vancouver Scar Scale and satisfaction scores after six months. (A) The level of the treatment effectiveness of the patients. (B) The level of the satisfaction of the patients.

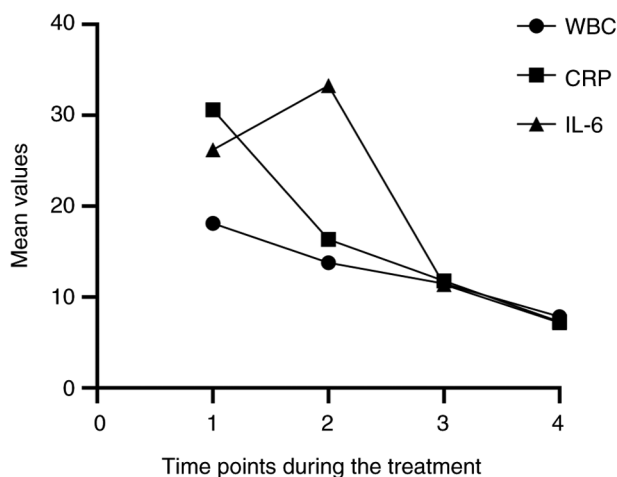


Figure 2. Temporal changes in the mean of three inflammatory markers (WBC, CRP, IL-6). The change in the mean values of the three inflammatory markers over time is shown. It can be found that the three inflammatory markers gradually decreased with time. Time points 1,2,3,4, represent 2 days before and after phase I surgery, and 2 days before and after phase II surgery, respectively. WBC, white blood cell; CRP, C-reactive protein.

(score, 11-15), with an effectiveness rate of 98.44%. In addition, 58 surgical patients were very satisfied, 5 surgical patients were satisfied and 1 surgical patient was dissatisfied, with a satisfaction rate of 98.43% (Fig. 1).

Observation of infection and inflammatory indices. The levels of inflammatory markers WBC, CRP and IL-6 in 64 patients exhibited a decreasing trend at the four time-points (2 days before and after phase I surgery, and 2 days before and after phase II surgery) (Fig. 2). WBC levels were significantly different among the four time-points ($P<0.001$), and the WBC 2 days after phase II surgery was significantly lower than the level at the other three time-points ($P<0.001$). There was a significant difference in CRP among the four time-points ($P<0.001$), and the CRP of patients 2 days after phase II surgery was significantly lower than that of the other three time-points ($P<0.001$). There was no statistical difference in IL-6 among the four time-points ($P=0.160$) (Tables I-III).

One typical case. A male patient aged 31 years was scalded on his right forearm and right dorsum due to hot plastic dumping, and was treated with anti-infection and local dressing change

on the wound following the injury. The patient was transferred to Guangzhou Red Cross Hospital (Guangdong, China) 2 days after the injury and was administered silver sulfadiazine cream and Vaseline oil gauze with finger dressing. The dressing was replaced on alternate days. At 9 days after the injury, the patient underwent phase I debridement and xenograft skin coverage treatment, and the dressing was changed on alternate days. Then, 7 days after the surgery, the patient underwent phase II debridement and autologous thin ITSG. The dressing was removed 7 days after the surgery, and all the skin grafts were well established. The patient was satisfied with the result, and his hand function recovered almost completely (Fig. 3).

Discussion

Burns, which can lead to damage to the skin mucosa and deep tissues, are one of the most common occurrences in surgical practice. There is now a consensus for early surgical treatment of deep burn wounds, with the functional recovery of the hand being particularly important for patients. For deep second-degree burn wounds on the hand, the traditional surgical approach is FTSGs or ITSGs after incision, to ensure the hand function recovers. Skin grafting of burn patients belongs to contaminated surgery thus the grafting area of the patients is easy to become infected and causing its inactivation. Simultaneous phase I skin grafting may lead to misjudgment of the tissue health status, residual necrotic tissue or the excision of too much normal tissue. In addition, it is often the case that some necrotic tissue left behind might lead to the inability of all skin grafts to be viable in phase I. In a previous study, the necrotic tissue was removed as thoroughly as possible during phase I surgery and cleared again during phase II surgery (based on the condition of the wound), leading to a reduction of the occurrence of inflammatory reactions and residual necrotic tissues affecting the survival of the skin grafts and improving the survival rate of the skin grafts (12). The results of the present study showed that the treatment of allogeneic skin coverage after early debridement and scabbing, followed by autologous thin ITSGs in phase II to repair deep second-degree burns on the dorsum of the hand, achieved improved results in terms of attenuating scar formation, restoring hand function and improving appearance following wound healing with high satisfaction.

In general, patients with burns experience large changes in body functions with a significant inflammatory response,

Table I. Repeated measurement of WBC of patients at 2 days before and after phase I surgery and 2 days before and after phase II surgery.

WBC (<10)	Mean	Standard deviation	F value	P-value
2 days prior phase I surgery	18.1280	2.63841	508.365	<0.001
2 days post phase I surgery	13.7917	1.80955		
2 days prior phase II surgery	11.4744	1.34734		
2 days post phase II surgery	7.8480	1.31109		

Greenhouse-Geisler estimate of the deviation from sphericity is $\omega = 0.776$. WBC, white blood cells.

Table II. Repeated measurements of CRP of patients at 2 days before and after phase I surgery, and 2 days before and after phase II surgery.

CRP (<7)	Mean	Standard deviation	F value	P-value
2 days prior phase I surgery	30.6020	19.83975	81.672	<0.001
2 days post phase I surgery	16.3586	5.04698		
2 days prior phase II surgery	11.7677	2.77063		
2 days post phase II surgery	7.2847	2.27631		

Greenhouse-Geisler estimate of the deviation from sphericity is $\omega = 0.350$. CRP, C-reactive protein.

Table III. Repeated measurements of patients' IL-6 at 2 days before and after phase I surgery, and 2 days before and after phase II surgery.

IL-6 (<7)	Mean	Standard deviation	F value	P-value
2 days prior phase I surgery	26.2131	15.20918	2.018	0.160
2 days post phase I surgery	33.2956	137.06445		
2 days prior phase II surgery	11.3713	2.27474		
2 days post phase II surgery	7.1795	2.02553		

Greenhouse-Geisler estimate of the deviation from sphericity is $\omega = 0.340$. IL-6, interleukin-6.

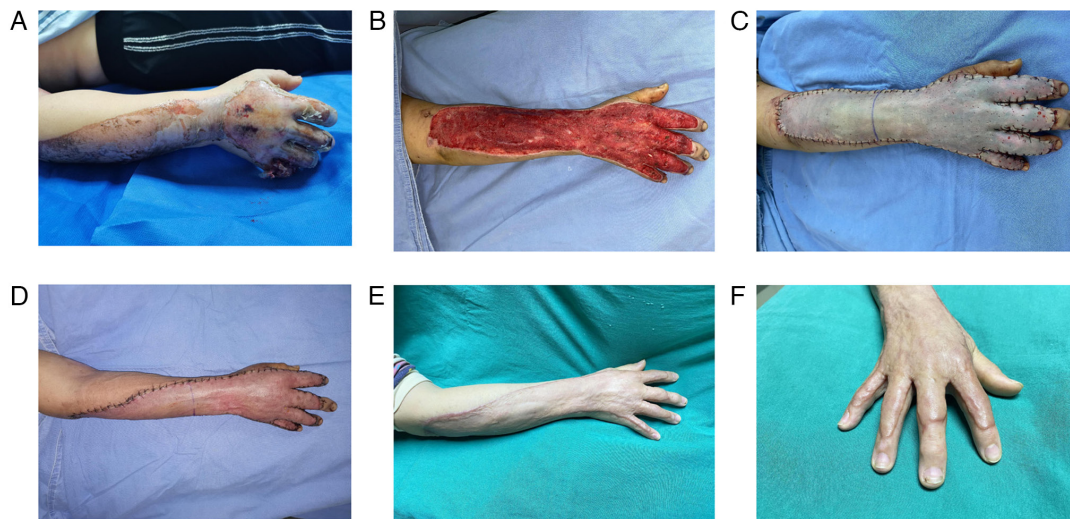


Figure 3. The skin of the patient who was scalded on his right forearm and right dorsum due to hot plastic dumping and was treated with anti-infection and local dressing change on the wound after the injury. (A) 2 days post-injury. (B) Phase II intraoperative. (C) Phase II skin grafting. (D) 7 days post phase II surgery. (E and F) Follow-up at 6 months post-healing.

which can lead to a significant imbalance of inflammatory factors. Continuous inflammatory response during this period can affect hand function, and the pathologically proliferative contracture of the scar following healing may also result in a local inflammatory response that further affects dorsal hand function (13,14). In general, allogeneic skin coverage following phase I surgical debridement can reduce the release of inflammatory mediators and establish a good foundation for autologous skin grafts in phase II, which is conducive to the functional recovery of the dorsum of the hand. With regard to the effect on the inflammatory response of patients, WBC, CRP and IL-6 gradually decreased at the four time-points (2 days before and after phase I surgery, and 2 days before and after phase II surgery) and the WBC and CRP levels of patients at the four time-points were statistically different in the present study. Various factors influence the systemic inflammatory response, with the severity of the burn often being the most important factor. The inflammatory response tends to diminish with time following the injury. Surgical trauma can be an aggravating factor, but the removal of necrotic tissue and effective coverage are also mitigating factors. In the present study, only the patients with $2\% \leq \text{burn area} \leq 10\%$ were selected in an attempt to minimize the complications caused by severe burns; however, there were patients with only 3% burn area who had the higher inflammatory response indexes in the 2 days before phase I surgery, so the sample size and the variety of inflammatory indices still need to be increased for further observation. By analyzing only the currently available data, phased surgical repair treatment was able to reduce the inflammatory response of patients and maintain the balance between each factor, which can enhance treatment efficacy and improve prognosis (15).

Deep burns in functional areas are often repaired using FTSGs/ITSGs, possibly due to the low prevalence of regular anti-scarring therapy and functional exercise (16). However, in the Burns and Plastic Department of Guangzhou Red Cross Hospital, burn patients are routinely administered anti-scar treatment and functional exercise after wound healing. In the present study, all patients had regular follow-up visits for anti-scar treatment and functional exercises. This could have been one of the factors that aided the healing of hand function via thin ITSGs transplantation (17).

The present study indicated that patients with deep second-degree burns of the hand are not significantly dysfunctional following clinical wound repair using thin ITSGs transplantation plus adherence to anti-scarring therapy and functional exercises. The authors look forward to conducting more relevant retrospective analyses and extended studies in the future. Based only on the currently available data, phase I allogeneic (porcine) skin grafts and phase II autologous thin ITSGs in patients with deep second-degree burns on the dorsum of the hand are ideal for treatment, as they can significantly reduce inflammatory reaction and improve patient prognosis. Following regular anti-scarring treatment and functional exercises, hand function was restored in the present study with satisfactory results.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

JES and SMS wrote the manuscript and contributed to the data analysis and interpretation. SSJ, GL and ZZ collected data and information of the case, and confirmed the authenticity of all the raw data. WHL and SYZ designed research and approved the final version of the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The present study was complied with the ethical guidelines of the Declaration of Helsinki and was approved by the Clinical Ethics Committee of Guangzhou Red Cross Hospital (approval no. 2021-153-01). Written informed consent was obtained from all the participants.

Patient consent for publication

Consent for publication was obtained from the patients.

Competing interests

The authors declare that they have no competing interests.

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