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# Comparing the Curative Efficacy of Different Skin Grafting Methods for Third-Degree Burn Wounds

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**Background:** Our research purpose was to compare the curative efficacy of different skin grafting methods for treating third-degree burn wounds.

**Material/Methods:** A total of 105 patients with third-degree burns were involved in this study. The burn wounds of these patients were treated using three different methods: Meek skin grafting, Stamp skin grafting, and Microskin grafting. Patients treated with different methods were placed in different groups. The skin graft survival rate, skin graft fusion time, wound healing time, total time of surgery, and 1% total body surface area (TBSA) treatment costs in each group were evaluated during and after the grafting procedures. After the operations, patients were followed up for 3 to 18 months in order to evaluate the postoperative outcomes.

**Results:** The skin graft survival rate was significantly higher in the Meek group compared to the rates in the Stamp and Microskin groups (both  $P < 0.01$ ). In addition, the skin graft fusion time, wound healing time, and 1% TBSA treatment costs were significantly lower in the Meek group compared to those in the Stamp and Microskin groups (both  $P < 0.01$ ). Furthermore, the Meek group exhibited better results with respect to curative efficacy, scarring status, and joint activity in comparison to the other two groups (both  $P < 0.05$ ).

**Conclusions:** The Meek skin grafting method showed better clinical efficacy for treating large wound areas in third-degree burn patients compared to the Stamp and Microskin skin grafting methods.

**MeSH Keywords:** **Burn Units • Transplantation, Autologous • Vascularized Composite Allotransplantation**

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## Background

Burns generally refer to injuries caused by exposure to heat emerging from diverse sources such as hot fluids (water, soup, oil, etc.), steam, gas, flame, and metal liquids or solids. Third-degree burns are also called eschar burns or full-thickness burns, destroying the outer layer of the skin (epidermis) and the entire layer beneath (dermis) [1,2]. Research on third-degree burns has generated sustained interest over the past few decades, and several important advancements have resulted in more effective patient stabilization and decreased mortality rates [1,3]. Techniques such as early wound debridement and early wound coverage with autologous skin graft have been shown to be effective in reducing burn mortality rates [4,5]. However, split skin grafting for extensively burned patients after their initial surgeries may be limited by the lack of autograft skin [6]. This factor may limit the excision of the eschar burn and delay the wound closure, thus leading to infection and septicemia [7]. To overcome this clinical barrier, various techniques have been developed to allow for skin graft expansion, such as Stamp skin transplantation [8], Microskin grafting [7], and the Meek skin graft technique [9]. Some experts argue that cultivating granulation tissue could be a viable treatment method; however, the consequences of this procedure often include more granulation tissue, longer repair times, and scar hyperplasia, which often lead to severe scar contracture and dysfunction [10]. Therefore, it is necessary and valuable to explore a more effective method for repairing burn wounds.

The Meek skin graft technique was developed by C. P. Meek in 1958 and can achieve expansion rates of up to 1: 9 [9]. The Meek skin graft technique adopted a new type of graft mechanization technology and was able to expand transplanted autogenous skin to close the burn wounds [11]. However, there is no previous research that has compared these three treatment methods (Meek skin grafting, Stamp skin transplantation, and particulate skin transplantation). There is no evidence regarding which one is superior for treating third-degree burns.

The purpose of this study was to conduct a retrospective study to examine and compare the curative effects of these three different graft methods on third-degree burn wounds by analyzing intra-operative data and post-operative clinical data. In particular, the intent of the current study was to describe our clinical protocol and provide clinical guidance for the successful use of these techniques for treating third-degree burn wounds.

## Material and Methods

### Study objects

From February 2013 to February 2015, 105 patients with third-degree burns were collected in The 253rd Hospital of PLA (Chinese People's Liberation Army) as subjects for this study. According to patients' conditions and permissions, those patients were divided into three different groups – the Meek group, Stamp group, and Microskin group – based on their corresponding treatment methods. Each group contained 35 patients. Subject inclusion criteria were individuals suffering from third-degree burns (1) who had burn areas ranging from 60% to 98% and third-degree burn wound areas  $\geq 20\%$ ; (2) who had no severe underlying diseases including heart failure, serious liver and kidney dysfunction, diabetes, and severe associated injuries; and (3) who had provided informed consent to the treatments according to the Medical Institution Regulations provisions released by the State Council. Procedures were in accordance with the Declaration of Helsinki and were approved by the Ethics Committee of Human Experimentation of The 253<sup>rd</sup> Hospital of PLA. All patients included in this study signed the written consent form.

### Surgical treatment

All surgeries were performed by senior surgeons. Patients were administered conventional anti-shock, anti-infection, organ support, and nutrition support treatments after hospital admission. Then, all patients were treated with general anesthesia. After removing the necrotic tissue on the wounds by sharp debridement, the third-degree burn wounds or partial deep second-degree burn areas of patients in each group were treated by Meek skin grafting, Stamp skin grafting, and Microskin skin grafting, respectively.

**Meek Group.** Patients in the Meek group were grafted with the Meek micro-skin technique. An electric dermatome (Zimmer, USA) was used to harvest autologous split-thickness skin at a thickness of 0.1–0.3 mm from donor sites. The dermis of the skin were spread inward using cork discs sized 4.2×4.2 cm, then placed in the Meek skin grafting machine (HUMWCA, Netherlands) twice for equidistant sawing, and fibrin glue (Tissucol Duo Quick, Baxter, Austria) was used to spray the epidermal surface of the micro skin. After ten minutes, the epidermises were adhered to polyamide chiffon, which was expanded in a two-way direction. Meanwhile, 196 pieces of micro skins, each with a size of 3 mm<sup>2</sup>, were spread evenly on the chiffon so that the expansion ratio of skin flaps ranging from 1: 9 to 1: 6 was achieved. If donor sites were ample, the expansion ratio was set between 1: 6 and 1: 4 in joints; if not, the expansion ratio was set between 1: 9 and 1: 6 in joints.

**Stamps Skin Grafting Group.** Patients in this group were treated with electric dermatome to remove skin flaps with 0.25 mm thickness from normal skin, and the skin flaps were then affixed to pieces of gauze with Vaseline. These larger gauze pieces were further cut down to pieces with a size of approximately 25 mm<sup>2</sup> and then were affixed to the wound.

**Microskin Group.** Patients in this group were treated with autologous particulate skin using the allogeneic skin grafting method. Autologous split-thickness skin was cut into microskins of 0.1 mm<sup>3</sup> size. The flotation method was used so that the microskin could be adhered to the surface of the large allogeneic skin. Then, the allogeneic skin was adhered to the wound, and the graft area was secured and bandaged properly in order to complete the procedure of skin graft.

Conventional antibiotics and nutrition support were used for patients after surgeries for the protection of organ function. Moreover, wound dressings were applied according to different wound conditions, and the first dressing was carried out approximately 3 to 6 days after the surgery.

#### Evaluation of skin grafting efficacy after surgery

The post-surgery survival rate of skin grafts, skin graft fusion time, wound healing time, total surgery time, and 1% total body surface area (TBSA) treatment cost for each patient were recorded and the corresponding data were analyzed.

#### Post-operative follow-up

Post-operative follow-ups were conducted for patients in all three groups, and the follow-up period ranged from 3 to 18 months. Data with respect to the curative efficacy and scarring status for each procedure were recorded accordingly.

The overall efficacy for each treatment was determined by the following criteria: *excellent*: the ratio of epithelialization healing area to transplantation area was more than 80% one month after transplantation or the corresponding ratio was larger than 95% one and half months after transplantation, and no further skin grafting was needed; *good*: the ratio of epithelialization healing area to transplantation area was between 50% and 80% one month after transplantation or the corresponding ratio was between 80% and 95% one and a half months after transplantation, and further skin grafting might be needed in the future; *poor*: the ratio of the two above-mentioned areas was less than 50% one month after transplantation or the corresponding ratio was less than 80% one and a half months after transplantation, and it would be essential to carry out further skin grafting surgeries for these patients in the future. "Excellent" and "good" were considered clinical curative.

Scarring status were measured by the Vancouver Scar Scale (VSS), which calculated abnormalities in pliability, thickness, hyperemia, and pigmentation, with scores ranging from 0 (best) to 15 (worst) [12]. The scar hyperplasia degree was divided into three levels: "light" (0–5 score), "moderate" (6–10 score), and "severe" (11–15 score).

#### Statistical analysis

All data were analyzed using SPSS 19.0 software (IBM, Chicago, Illinois, USA). Counted data were analyzed by using the chi-square test; measurement data were displayed as mean ± standard deviation (SD); and the Kruskal-Wallis test was used for pairwise group comparisons. A *P* value less than 0.05 was considered to be statistically significant.

## Results

#### Baseline characteristics of study objects

The baseline characteristics of patients were compared across the three patient groups. These included sex ratio, age, burn areas, third-degree burn wounds, time elapsed before patient admission, causes of burn injuries, and any complications resulted from surgery. There were no significant differences in these indices among three groups (*P*>0.05), as shown in Table 1.

#### Evaluating the skin grafting status for each treatment

The corresponding skin grafting status was evaluated after treatments were applied to the patients in each group (Table 2). The corresponding skin graft survival rate for each group was 91.76±1.5% (Meek), 76.24±3.97% (Stamp), and 73.55±2.85% (Microskin). We observed that the skin graft survival rate in the Meek group was significantly higher than those in the other two groups (*P*<0.01). Moreover, the skin graft fusion time in each treatment group was 11.61±1.59 d (Meek), 16.79±2.51 d (Stamp), and 18.37±2.63 d (Microskin), suggesting that the average fusion time in the Meek group was significantly lower than those in the other two groups (*P*<0.01). The wound healing times of the three groups were 30.78±3.18 d (Meek), 46.26±9.93 d (Stamp), and 48.49±7.53 d (Microskin), indicating that the average healing time of Meek group was significantly lower than those of the other two groups (*P*<0.01).

#### Evaluating the overall characteristics of three skin grafting techniques

We also compared the total surgery time and the 1% TBSA treatment cost among the three treatment groups. The total surgery time for the Meek, Stamp, and Microskin groups was 3.14±0.64 hours, 3.26±0.66 hours, and 3.18±0.68 hours, respectively,

**Table 1.** Baseline characteristics in the three groups.

| Characteristics                           | Meek group  | Stamp group | Microskin group | P value            |
|---|-------------|-------------|-----------------|--------------------|
| Gender (Male/Female)                      | 25/10       | 27/8        | 23/12           | 0.571 <sup>#</sup> |
| Age                                       | 41.46±11.94 | 42.38±11.54 | 40.84±10.37     | 0.778*             |
| Burns area (cm <sup>2</sup> )             | 73.72±10.48 | 71.27±10.06 | 73.51±10.29     | 0.534*             |
| III degree burns wound (cm <sup>2</sup> ) | 36.18±10.09 | 34.54±11.17 | 35.89±9.24      | 0.707*             |
| Time before admission (d)                 | 63.39±1.20  | 3.12±1.16   | 3.13±1.27       | 0.608*             |
| Causes of burn injuries                   |             |             |                 | 0.409 <sup>#</sup> |
| Hot liquid burn                           | 13          | 14          | 13              |                    |
| Flame burn                                | 21          | 18          | 22              |                    |
| Chemical burn                             | 1           | 3           | 0               |                    |
| Complications                             |             |             |                 | 0.928 <sup>#</sup> |
| Inhalation injury                         | 13          | 12          | 12              |                    |
| Stress ulcer                              | 9           | 10          | 8               |                    |

\* Using Kruskal-Wallis test; <sup>#</sup> using chi-square test.

**Table 2.** The postoperative skin grafting conditions of the three groups.

| Index                        | Meek group | Stamp group | Microskin group | P value |
|------------------------------|------------|-------------|-----------------|---------|
| Skin graft survival rate (%) | 91.76±1.5  | 76.24±3.97  | 73.55±2.85      | <0.001* |
| Skin graft fusion time (d)   | 11.61±1.59 | 16.79±2.51  | 18.37±2.63      | <0.001* |
| Wound healing time (d)       | 30.78±3.18 | 46.26±9.93  | 48.49±7.53      | <0.001* |

\* Using Kruskal-Wallis test.

**Table 3.** The other conditions of the three skin grafting methods after treatment.

| Index                         | Meek group     | Stamp group    | Microskin group | P value |
|-------------------------------|----------------|----------------|-----------------|---------|
| Total time of the surgery (h) | 3.14±0.64      | 3.26±0.66      | 3.18±0.68       | 0.742   |
| 1% TBSA treatment costs (rmb) | 4999.41±606.33 | 6722.31±598.32 | 7186.36±567.44  | <0.001* |

TBSA – total body surface area; \* using Kruskal-Wallis test.

suggesting that the average total surgical time was not significantly different between the three groups. Furthermore, the 1% TBSA treatment cost for each treatment group was 4999.41±606.33 RMB, 6722.31±598.32 RMB, and 7186.36±567.44 RMB, respectively ( $P<0.01$ ), indicating that the Meek group had significantly lower 1% TBSA treatment costs compared to the other two groups. The above comparisons are displayed in Table 3.

### Comparing the overall efficacy for each treatment

As suggested by Table 4, there were 26 excellent cases, 6 good cases, and 3 poor cases in the Meek group with a curative rate

of 91.43%; there were 15 excellent cases, 9 good cases, and 10 poor cases in the Stamp group, which exhibited a curative rate of 68.57%; and the Microskin group contained 13 excellent cases, 10 good cases, and 12 poor cases, with a curative rate of 68.57%. The curative rate in the Meek group was significantly higher than those in the Stamp and Microskin groups ( $P<0.05$ ).

### Post-operative wound hyperplasia of patients

In the Meek group, post-operative scars were reticular with a light degree of hyperplasia, and no case displayed moderate or severe scar hyperplasia. The scars appeared to be soft and

**Table 4.** Comparisons of therapeutic efficacy after treatment.

| Groups          | Excellent | Good | Poor | Curative rate (%) |
|-----------------|-----------|------|------|-------------------|
| Meek group      | 26        | 6    | 3    | 91.43             |
| Stamp group     | 15        | 9    | 10   | 68.57             |
| Microskin group | 13        | 10   | 12   | 65.71             |
| P value         | 0.025*    |      |      |                   |

\* Using chi-square test.

**Table 5.** Postoperative wound hyperplasia of patients in the three groups.

| Index  | Meek group | Stamp group | Microskin group | P value |
|--|------------|-------------|-----------------|---------|
| Light scar hyperplasia                             | 35         | 29          | 29              |         |
| Moderate scar hyperplasia                          | 0          | 3           | 4               |         |
| Severe scar hyperplasia                            | 0          | 3           | 2               | 0.736*  |
| Lysis of cicatricial contracture and scar grafting | 0          | 4           | 3               |         |

\* Using chi-square test.

flat, and the cicatricial contracture in the joints of patients was not severe. Moreover, joints acted freely after functional exercise, and no lysis of cicatricial contracture was detected. In the Stamp group, there were three cases of moderate scar proliferation and three cases of severe scar proliferation. Meanwhile, four cases of cicatricial contracture in the joints of patients were detected in this group, and skin grafting surgeries were undertaken to rectify those. In the Microskin group, there were four cases of moderate scar proliferation, two cases of severe scar proliferation, and three cases of cicatricial contracture in the joints of patients. In conclusion, the number of scars in the Meek group was less than the number in the other two groups, and patients in the Meek group exhibited better joint functional recovery compared to patients in the other two groups (Table 5).

## Discussion

Great advancements in the treatment of burn wounds have been made in the past few decades [13–15]. However, third-degree burns, which mean all the skin layers are destroyed and the subcutaneous tissues are potentially damaged, are still extremely difficult to treat due to the lack of donor sites [16]. Traditional skin grafting methods such as Stamp skin or Microskin are challenged by the undesirable clinical outcomes [17]. Meek skin grafting, first introduced by C. P. Meek in 1958 [9] and then further modified by Kreis et al. in 1993 [18], is notable for its high expansion rate. The Meek technique is widely adopted when the TBSA of third-degree burns is more than 40% to 50% [17]. In our study, the Meek skin grafting method is a

reliable alternative compared with the Stamp and Microskin grafting methods for third-degree burns.

After surgery, the majority of all skin grafts in the three groups survived. The skin graft survival rate of the Meek group even reached 91.76%, and such a result was consistent with previous studies. Lari and Gang also found that 90% of the graft skin survived on the seventh day after surgery [7]. In our report, patients who received a Meek graft showed a significantly higher skin graft survival rate than those in the other two groups. Such a remarkable difference between the Meek and Stamp methods was also recorded by Menon et al. [19]. However, Lumenta et al. reported only a 70% survival rate of patients who were treated with the Meek grafting method [17]. The smaller sample size of the latter study may be a possible explanation for its results since they recruited only 17 patients. Another possible explanation is the variation in the selection of the expansion ratio since they applied a ratio of 1: 9 micrograft to all of their patients, whereas our study adopted a variable ratio that depended on the corresponding burn areas of patients.

Previous evidence with respect to skin convergence and wound healing time suggested that implementing Meek with a cultured epithelial autograft in pediatric burns had an average wound closure period of nine days [19]. Our study indicated a significantly shorter wound healing time in the Meek graft group compared to the other two groups. Meanwhile, Meek was associated with lower surgical costs and faster recovery of patients with third-degree burns, and was more affordable than the other two techniques.

Our follow-up studies also provided evidence that more than 90% of patients who underwent the Meek grafting procedure exhibited a good post-operative recovery status. In addition, the Meek group had fewer poor cases and fewer cases that potentially required secondary skin grafting techniques. Patients in the Meek group had relatively milder scar hyperplasia as compared to patients in the Stamp and Microskin groups. Similarly, Hsieh et al. demonstrated that the texture of the scars resulted from Meek grafts appeared to be pliable after surgeries [20].

For further research studies, post-operative infections, length of hospitalization, and long-term side effects could be involved in the evaluation of the clinical efficacy and safety of the Meek skin graft method compared to other methods. Lari and Gang have recorded the incidence of methicillin-resistant *Staphylococcus aureus* (MRSA) infection and medina in Meek skin graft patients [7]. A study also found that patients tended to suffer from *Pseudomonas aeruginosa* infections after Meek skin grafts [21]. However, there are no studies that compared the infection rates of patients in the Meek group versus non-Meek group patients. Other issues, such as the length of hospitalization and long-term side effects, also deserve further

exploration. Lumenta et al. claimed that the Meek technique had no significant effect on the length of hospital stay, but such a result was not conclusive due to the aforementioned smaller sample size [17]. Therefore, further research is required in order to support these conclusions.

## Conclusions

The Meek skin graft method is an ideal treatment that not only provides enhanced efficacy but also has great affordability in comparison to other techniques. This study may also guide us to further explore potential improvements with respect to wound care and functional recovery of patients who suffer from burn injuries. However, there were some limitations in our research. For instance, the conditions of patients such as the areas and proportions of donor site and recipient site, which are important factors in skin graft fusion time and wound healing time, should be discussed in further research.

## Conflicts of interest

The authors have no conflicts of interest to declare.

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