The Art of Skin Graft

Advanced Graft Technique

Young-Chul Jang

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ISBN 978-981-97-0016-5 ISBN 978-981-97-0017-2 (eBook)
https://doi.org/10.1007/978-981-97-0017-2

Preface

Now, skin graft is not exclusive to plastic surgery but a fundamental technique required by all surgical departments, and it has a significant impact on the end results of surgery. Split-thickness skin graft , a common technique for treating traumatic injuries, causes frequent functional disorders due to contractures occurring during the healing process. Full-thickness skin graft is useful for joint contracture corrective surgery; however, its disadvantages include insufficient donor sites and poor skin survival. I wrote this book to reiterate the concept of skin graft, which has been regarded as an old, conventional surgical technique by most surgeons so far, and to highlight the advancements and usefulness of such techniques. Therefore, I majorly delineated skin graft in terms of its techniques and described the concepts of advanced skin graft methods, including aesthetics, which are often encountered in reconstructive surgery, as well as basic techniques.

I named this book *The Art of Skin Graft* for the purposes of reinterpreting skin graft, which has been one of the most popular surgical techniques, from a new perspective. Such efforts were made because it was thought that cosmetic improvements in terms of aesthetics and functionality by the addition of artistic sensibilities to conventional ideas would be of help to patients who have been suffering for a long time. This book was written with the hope of providing guidance for those who want to be surgeons, by putting together all the bedside teaching and instructions I have given as a professor to students and junior colleagues and all the experiences of hope and despair that I have felt while performing more than 10,000 surgeries.

Finally, some questions in this book remain unanswered for several clinical cases, such as those related to cell culture and artificial dermis, which have not been scientifically proven as real artificial skin. This book was written with the hope of receiving answers to such questions from young surgeons who are constantly improving their abilities and have the spirit of research.

Finally, I would like to express my heartfelt thanks to the many patients who believed in, followed, and taught me for a long time, helping overcome numerous difficult problems.

Seoul, Korea (Republic of) Young-Chul Jang

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1

1.1 Introduction

Split-thickness skin graft (STSG) refers to a type of widely used skin graft that comprises both the full layer of the epidermis and a part of the dermis [1–4]. This technique can be categorized into a mesh skin graft, which is mainly used to treat cases of burns or trauma, and STSG, a convenient and effective method that is typically used for skin defects and wound healing. Surgical method used for a mesh skin graft is a simple reliable effect, and the take rate is considerably high; thus, most cases are dismissed as simple operations without careful consideration regarding the operation itself [5]. However, the author would like to emphasize that a thoroughly planned operation, even for a mesh skin graft, is very effective, plays an important role in the wound healing process, and greatly affects the outcome. Moreover, owing to the fact that it considerably influences the mesh pattern scars that inevitably remain, along with the need for corrective surgery for severe contractures on joints and unsightly scars on the exposure area, careful consideration and implementation of the mesh ratio, engraft mesh direction, and regions to be avoided is important [6]. In addition, in cases in which mesh skin graft is possible, shortening the wound healing process is a crucial point of the surgery [7]. Therefore, if the mesh ratio is 1:3–4 or higher, the combined use of cultured epithelial cell therapy and dermal substitute to minimize scar contracture is efficient in supplementing the dermis. Therefore, an introduction to this method will be briefly described. Please note that the introduction to this method is described in Chap. 4 "Cultured Epithelial Cell Therapy" in more detail [8–11].

STSG is the most widely performed skin grafting procedure; however, in this section, rather than introducing the basic principles or technical aspects of general STSG, a practical introduction to the components of the procedure that have a great influence on the functional and cosmetic results of surgery, such as the face and hands, will be provided. In particular, the author will discuss the considerations and operative results of facial skin graft, which remains very controversial among plastic surgeons in terms of whether or not the surgery should be performed. STSG is rarely used in most reconstructive surgery procedures owing to the frequent problems related to high contracture rate and pigmentation disorder. This work describes the author's long-accumulated methods for and results of upper and lower lid ectropion correction, which is considered one of the most difficult to achieve in terms of natural and functional recovery. Furthermore, this section will highlight the usefulness of STSG, which has not received much attention because it is dismissed as a simple operation, and provide an opportunity to expand its scope of use [12, 13].

Y.-C. Jang, *The Art of Skin Graft*, https://doi.org/10.1007/978-981-97-0017-2_1

1.2 Mesh Skin Graft

The primary purpose of a mesh skin graft is to effectively cover a large area of skin defect with a relatively smaller area of the skin. Furthermore, this method is particularly useful for rapid wound coverage because blood or fluid can be discharged through the mesh gap, thereby making the process of wound dressing easy [14]. In addition, this method has the highest engraftment rate. However, it is recommended to avoid this method for parts that are exposed to the external environment, such as the face, back of the hands, or forearms; this is because the mesh pattern scar that occurs as a result of the rapid treatment lacks a cosmetic effect. This method should also be avoided for large joints of the extremities that move considerably as well as the hands or feet, i.e., areas with a large number of joints, as the scar contracture rate is high.

In general, the mesh ratio ranges from 1:1 to 1:2 using a mesher machine (Brennen skin graft Mesher) [15].

In cases in which no expensive mesher machines are available, the skin collected with a No. 10 blade is spread flat on a hardwood or rubber board and is used conveniently by overlapping the interrupted slit incision (Fig. 1.1) [16]. The advantages of this method include easy adjustment of the mesh ratio by the operator and a less apparent mesh pattern than expected, thereby increasing the engraftment rate and ensuring the safety of this method when used for grafting [17]. However, in cases requiring wide wound coverage, such as in a patient with major burns, a mesher device is absolutely necessary owing to the fact that a ratio of 1:4 or even 1:9 may be used. If the mesh pattern ratio is >1:4, the time required for filling the mesh gap with epithelialization increases and lowers the engraftment rate. Accordingly, the author has been able to obtain satisfactory results by shortening the healing period using the sandwich technique with cultured epithelial homograft (CEH) and proceeding with stable wound healing. Owing to the fact that a cultured epithelial autograft (CEA)

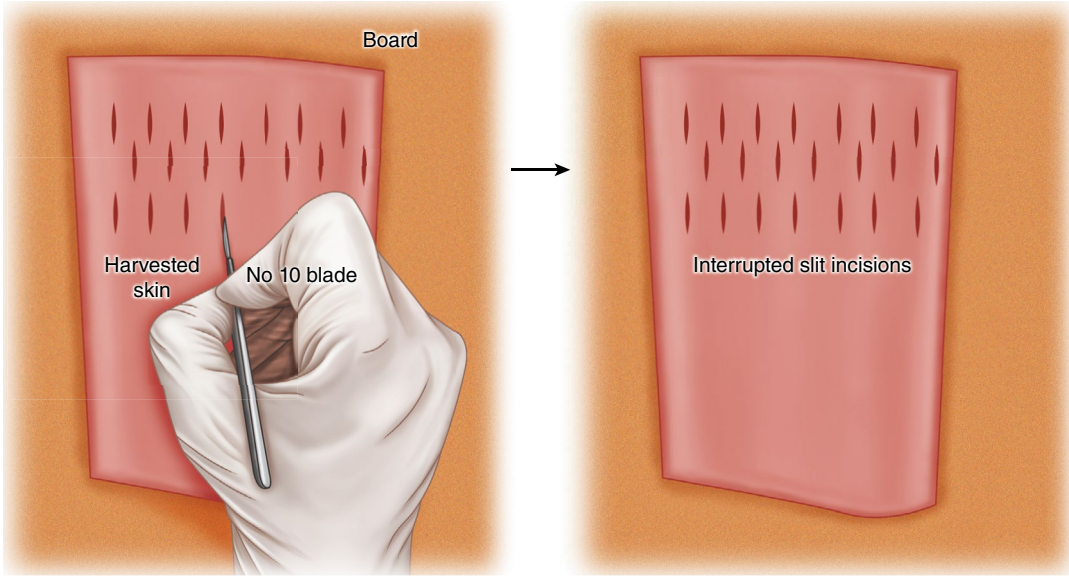

Fig. 1.1 The harvested split-thickness skin is spread flat on a hardwood or rubber board and overlapping the interrupted slit incisions with No. 10 blade to make mashed auto split-thickness skin

provides coverage using one's own cells, it provides better results than CEH in terms of increasing the engraftment rate, shortening the healing process, and replenishing small but insufficient skin [11]. This method will be described in more detail later along with a clinical case example.

Mesh skin graft is a very important and critical method used for burn management, but both plastic surgeons and patients must carefully consider this procedure and avoid using it in cases when it is not absolutely necessary. One reason for exercising this caution is to avoid wasting the sacrifice of another donor to correct the mesh-shaped deformity later. This concept will be explained in further detail in Chap. 5 (Esthetic skin grafting). Another reason is that regardless of the quality of the mesh skin graft, it will eventually undergo deformation and contracture deformation. Therefore, correction should be performed as soon as possible. Introducing a high-quality sheet graft will not only save time and money but also produce excellent results. In other words, performing a high-quality split-skin graft method can yield many benefits, such as convenience and reduction of skin consumption during future functional or cosmetic corrective surgeries. These concepts are especially important for the face and hands; therefore, the surgeons should familiarize themselves with the details given in the "STSG" section.

The surgical method and postoperative management of mesh skin graft are relatively simple. In my cases, after carefully selecting the surgical site, a protective dressing is applied using Bactigras (Smith & Nephew Medical Ltd., Hessle Road, England), a Vaseline gauze with a large mesh pattern that facilitates good fluid evacuation, followed by a saline-soaked compression gauze dressing. A stable engraftment generally begins when the dressing is opened after 3–4 days. Most meshes with a 1:2 ratio engraft well without major changes; however, the time taken for epithelialization and wound healing is delayed and skin loss is observed when the ratio exceeds 1:4. Therefore, personally using CEH in combination is considered efficient; however, its high cost remains the biggest obstacle [18]. In addition to this method, CEA, in which one's own epithelial cells are cultured and permanently engrafted in one's body, can obtain better results, but the incubation period is more than 2–3 weeks [19], and the cost is much higher than that of CEH. Thus, such unrealistic disadvantages must be overcome. In addition, the combined use of the human dermal matrix that replenishes the dermis in the joint area can also alleviate contracture deformities, which are a disadvantage of the mesh skin graft. However, the high cost of this method remains as an unresolved issue [20–22]. A clinical introduction to these techniques will be described in more detail in Chaps. 3 and 4, and only the basic cases will be briefly introduced here; rather than simply choosing a mesh graft for its generally simple, burden-free surgical method with a high engraftment rate, it is very important to make a decision after carefully considering the condition of the wound bed, the patient's general condition, the donor's general condition, the selection of areas to be avoided, and the corrective surgery that will be required in the future. The author does not consider mesh skin grafts using a mesher as an option unless it is absolutely necessary. However, in places where bleeding control is not easy, such as axilla, shoulder, and knee joints with larger and frequent movements, a No. 10 blade mesh technique is used to adjust the interval of the interrupted slit incision in place of using a mesher. The advantage of this method is that there is no need for an expensive mesher, it is fast, and the degree and width of the mesh can be arbitrarily adjusted as desired. In addition, the No. 11 blade can be selectively used if necessary as part of the graft [23]. Furthermore, the deformity caused by the mesh pattern is less than expected; thus, it is recommended to distinguish between a mesh skin graft in which a mesher is used to graft for wide area coverage and adjusting the appropriate mesh rate by simply using a slit incision. In cases when the range is not particularly wide, it is recommended to use the manual mesh method, if applicable.

Fig. 1.2 (**a**) The problem of the skin graft by displaying a visible mesh pattern deformity on the face. (**b**) Severe scar contracture deformities were noted on the dorsum of the hand with dislocated multiple finger joints

This patient exemplifies the problem of the skin graft by displaying a visible mesh pattern deformity of the face, ectropion of both lower lids, and severe scar contracture deformities of the hands, resulting in serious functional and esthetic deformities. Because the author strongly recommends more active early management and proper skin graft selection in the acute stage, surgeons should keep this in mind (Fig. 1.2). A considerable amount of time and effort is needed to correct these problems, which thoroughly demonstrates that the use of a mesh skin graft is contraindicated for the face and hands.

This image depicts a comparison of CEH in an experimental study for rapid healing of wide-mesh grafts, showing a difference in healing time. This figure shows how CEH can effectively epithelialize a large gap in a mesh skin graft and aid in wound healing.

A 42-year-old male patient suffered a flame burn on his right lower leg. (a) Ten days after the procedure, debridement and a 1:3 mesh skin graft

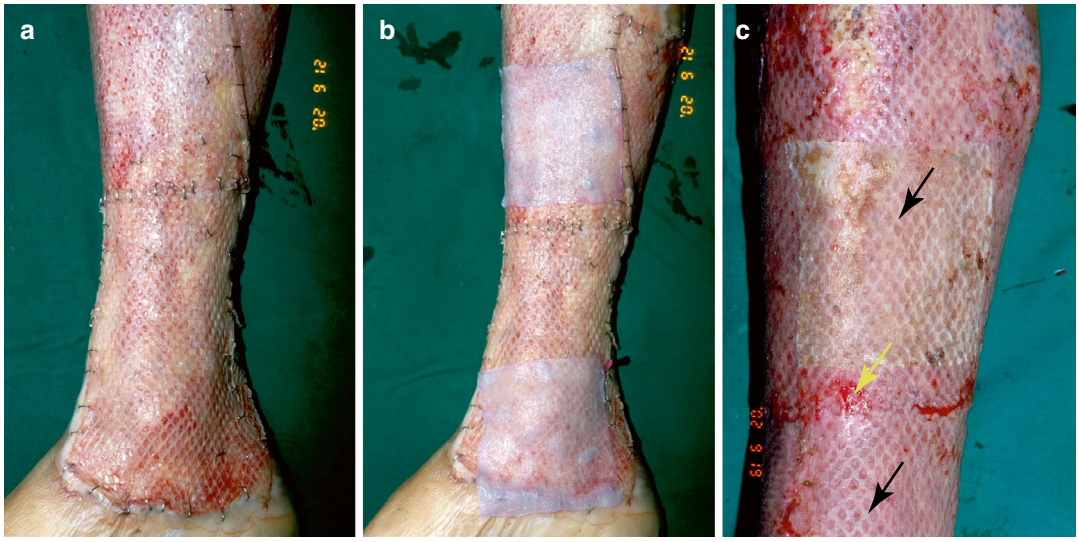

Fig. 1.3 (**a**) 10 days after operation, debridement and 1:3 meshed skin graft was performed. (**b**) Three sheets of CEH were applied on the anterior tibial area. (**c**) After 1 week, well rapid epithelialization was noted on the CEH application site (black arrow) and comparison to the CEH gap site (yellow arrow)

were performed, and (b) three sheets of CEH were applied experimentally on the anterior tibial area. (c) After 1 week, rapid epithelialization was observed on the CEH application site (black arrow) in comparison to the CEH gap site, which remained unhealed (yellow arrow) (Fig. 1.3).

The healing pattern also showed that the epithelialization between the meshes is much more stable, and the contracture progress is less developed, showing a significant difference in the healing process.

This patient was involved in a traffic accident that resulted in an above-knee joint amputation, and the raw surface was left open for more than 2 months, delaying wound healing. We applied a human dermal matrix with a 1:4 mesh skin graft. Shown on figure 1.4, you can see the differnces between the two divided areas, the area that is indicated with black arrow is where CEH was applied shows greater density epithelialization.

In comparison to the area (marked in yellow arrow), where CEH was accidentally removed after one day, shows significant difference in healing progress.

Figure 1.5 shows a reconstructive surgery that was performed to correct a severe scar contracture in a 6-year-old female patient. A 1:6 wide-mesh

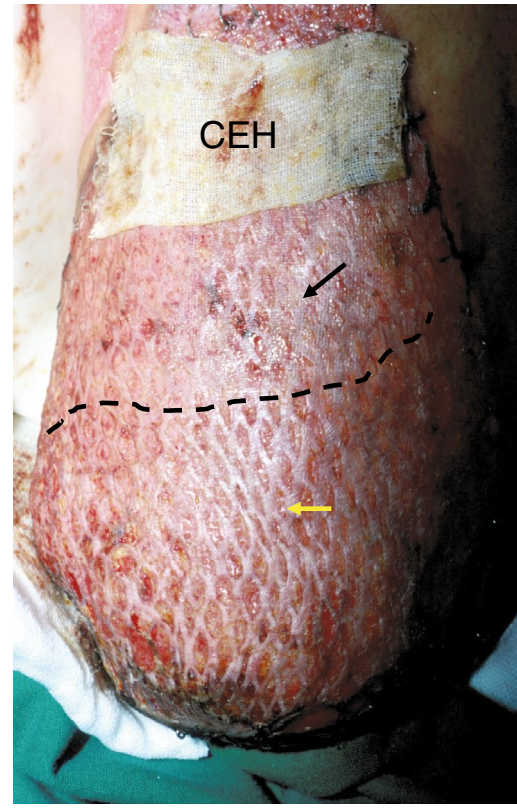

Fig. 1.4 Human dermal matrix with 1:4 mesh skin graft and covered with experimental CEH (above the dashed line). Note the different healing pattern on upper and lower parts

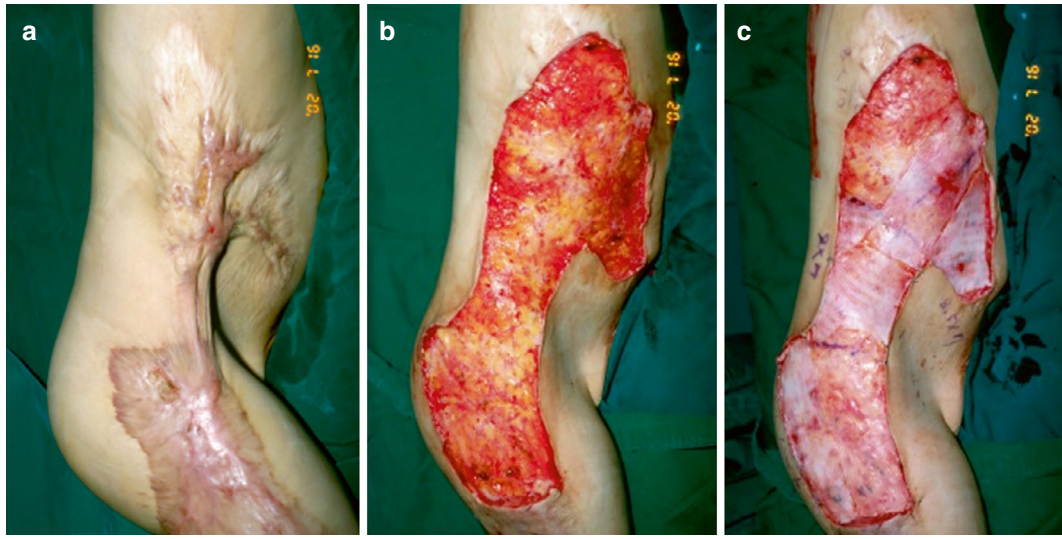

Fig. 1.5 (**a**) Severe linear scar contracture line observed with functional disturbance. (**b**) Incisional and excisional full release. (**c**) The human dermal matrix with 1:6 meshed skin graft was performed for dermal volume replacement, and CEA was covered on the top for rapid meshed gap fill with epithelialization

skin graft was performed after preparing a human dermal matrix to replenish the dermal layer, and CEA culture grafts were prepared 2 weeks in advance. At 6 and 12 days after the operation, the CEA petrolatum gauze was completely removed, and the entire mesh gap was epithelialized without difficulty.

Six days after the operation, epithelialization developed rapidly with a stable wound healing process. (b) Twelve days after the operation, the CEA petrolatum gauze and the engrafted mesh skin were completely removed, and the mesh gaps were completely covered with the patient's own epithelial cells (Fig. 1.6).

These above clinical studies have shown that the cultured epithelial graft is a very effective wound healing process and less scarring even with a 1:6 large mesh ratio [24]. However, the production cost of human dermal matrix and CEA was very high and required 2 weeks, which is a major drawback and remains an unresolved problem. Therefore, the author has developed a cell spray technique to reduce the production cost and time of CEA culture.

A 47-year-old man suffered flame burns on his left shoulder and back. Escharectomy was performed on day 17 of the incident, and a 1:4 mesh skin graft was introduced, followed by the application of three bottles of cell suspension with a fibrin sealant using tissomat cell spray (duproject spray). The three bottles were prepared 2 weeks before escharectomy (Fig. 1.7). Five days after the operation, the lower part of the operation site started healing and successfully retained the engrafted mesh skin on the shoulder area. One week after the operation, epithelialization markedly increased, and mesh gaps were almost healed. Ten days after the operation, the graft was taken completely, and the wound on the mesh gaps had healed (Fig. 1.8). This technique was observed to have a quick culture time, usually 2 weeks, short waiting time of no more than two weeks, which cuts the cost of producing the sheets. This spray technique is very effective on difficult-to-reach wound areas such as dimensional body parts like the axilla, shoulder, upper arm, and larger surface areas.

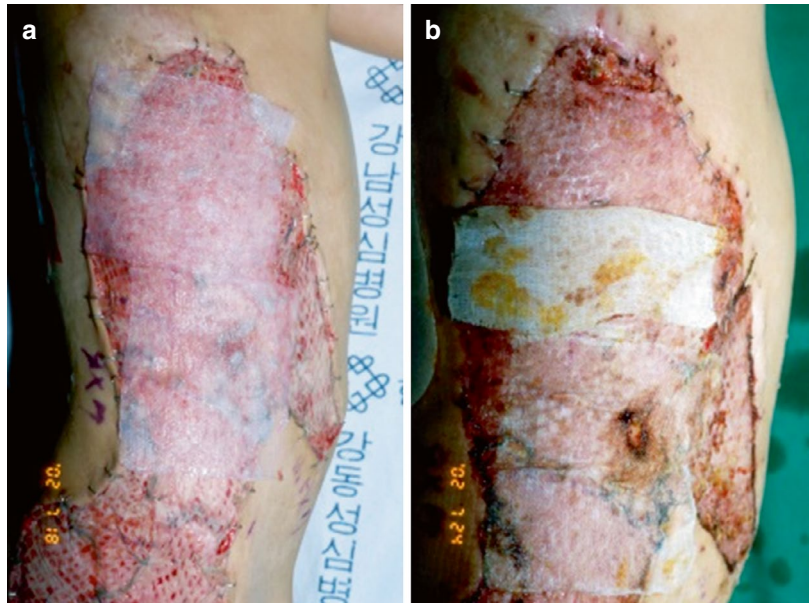

Fig. 1.6 (**a**) 6 days after the operation, the epithelialization was developed very rapidly with stable wound healing process. (**b**) 12 days after surgery, the CEA petrolatum gauze was peeled off and noted engrafted meshed skin was 100% graft take rate

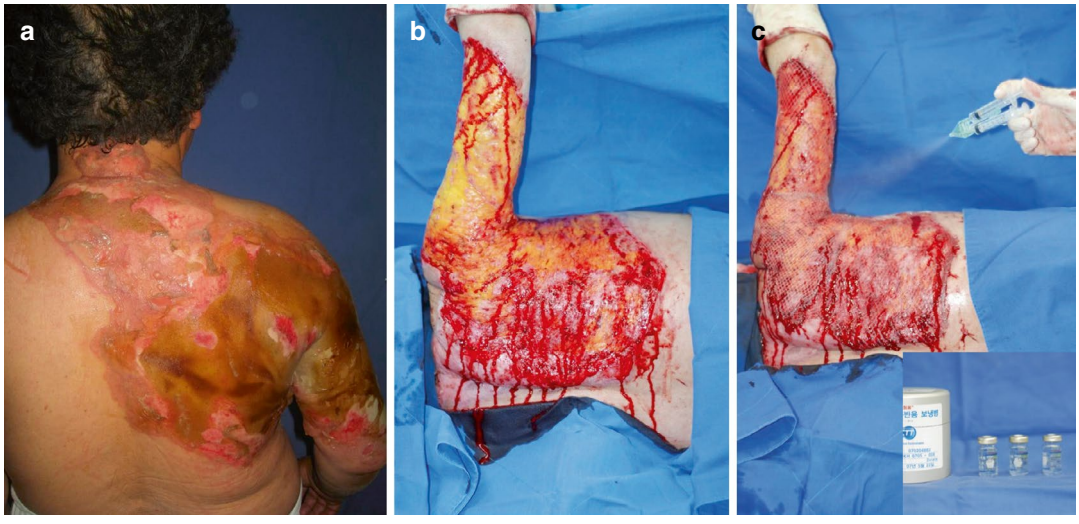

Fig. 1.7 (**a**) This man suffered flame burn on the right shoulder and back area. (**b**) Escharectomy was performed on burn day 17. (**c**) 1:4 meshed skin graft was performed, and three bottles of cell suspension with fibrin sealant were applied

As a plastic surgeon, I personally do not prefer mesh skin grafts, but since they are essential for the management of major burns or extensive wounds, methods using CEH, CEA, and cell spray techniques that are quick and also facilitate wound healing were briefly introduced in this chapter, especially cell spray technique was observed to have a quick culture time, usually 2 weeks, with none usage of the sheets that are high in cost. This will be described in detail in Chap. 4 Cultured Epithelial Cell Therapy.

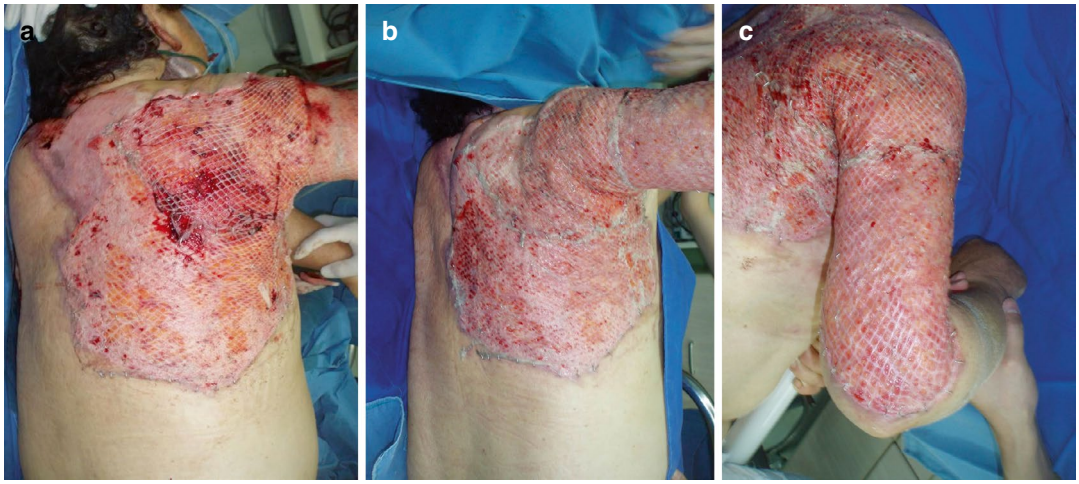

Fig. 1.8 (**a**) Postoperative day 5, operation wound was opened. (**b**) One week after the operation, marked epithelialization was noted. (**c**) Postoperative day 10 after view, 100% graft take rate was shown

1.3 Split-Thickness Skin Graft

STSG is a representative skin graft technique that grafts the full layer of the epidermis and part of the dermis using a hand or electric dermatome or skin-sampling knife. This is a useful method that can cover a wide area of a wound. In addition, because the skin engraftment is better than a full-thickness skin graft (FTSG), STSG can quickly and effectively cover and treat burns or trauma. It is the most frequently used and widely known method owing to the fact that it can be easily used in all cases of small wound size by collecting a sample with a razor or Blair/Humby knives, for slightly larger sites. However, the texture of the transplanted site is poor, with pigmentation that is not harmonious with the surrounding tissue and is prone to contracture deformation leaving large pigmentation lesions with rough, irregular hypertrophic scars on the donor site, indicating that STSGs lead to functional and cosmetic damages. Moreover, as compared with FTSG the secondary contracture of the engrafted skin surface is observed after engraftment, consequently affecting the surrounding tissues, and scar contracture deformities become unavoidable. However, if more systematic management of graft thickness, appropriate engraft timing, bleeding control, and postoperative dressing are ensured, more satisfactory functional and cosmetic effects can be achieved while managing acute hand burns; moreover, subsequent reconstructive surgery may not be required.

Therefore, the author prefers an intermediate thickness that does not exceed 0.25–0.3 mm (10–12/1000 inches) for most skin thicknesses. Recently, prevention of unsightly scars of the donor site has garnered a considerable degree of interest; thus, the author focused on an accurate excessive doner collection is avoided from the selected doner site, keeping it thinnly as possibe no more than 0.3 mm in thickness (12/1000 inches).

In the case of the author, a thickness of up to 0.38–0.5 mm (15–20/1000 inches), thick STSG can be used in cases in which a high-quality texture of the skin is considered, such as for the correction of the upper and lower lid ectropion or scar contracture correction around the nose,

mouth, and eye regions. It is rarely used in my case except for special purpose of reconstruction. Considering donor site morbidity, severe or mild hypertrophic scarring or unsightly and rough scars may apparently remain according to difference of individual tendency of scarring. I highly recommend when it is possible that surgeons should aim to harvest skin from donor areas that are less visible to the patient such as the buttock and the back, instead of selecting donor areas that are much more visible such as the upper and inner thighs. Recently, with the development of an artificial dermis, a method has been developed to minimize graft construction by supplementing the thickness of the dermis. Collecting an ultra-thin 0.12–0.2 mm (5–8/1000 inches) donor skin and using an artificial dermis, it provides medium or thick STSG effect. It has now become possible to avoid donor site morbidity and scar formation to some extent. This method can be particularly useful for children who are prone to hypertrophic scarring or for older adults who do not have good skin donor sites because of their very thin aging skin. However, the considerable economic burden is a major disadvantage. As such, STSG has a great effect on the construction of the surgical site, pigmentation, and the texture of the skin, depending on the thickness of the dermal layer harvest to be collected. Recently, surgeons have shown a proclivity to avoid leaving scars on the patient's body if possible. Thus, donor site morbidity must be considered more importantly. In accordance, the thickness of the skin to be collected, donor site, area, and shape must be carefully considered, and to obtain a graft of an accurate size and a constant thickness, hand skills using a dermatome or various knives must be acquired through ceaseless efforts.

1.3.1 Donor Site Skin Collection Method

Although manual hand drum Padgett dermatomes were used in the past, these dermatomes were difficult and complicated to operate, and there are risks of explosion from the adhesive used to adhere to the skin surface and the ether solution used to dissolve it [25]. Therefore, it is now rarely used. Sometimes the author uses this instrument when necessary for esthetic skin grafts that require the desired shape and exact thickness [26–28]. Lately, a mechanical dermatome is generally used, an electrical or pneumatic-type driving method that is driven by N_2O gas. The author personally prefers using the pneumatic type owing to its good strength and sturdiness. The size of the skin collected is 2.5, 5, 7.5, or up to 10 centimeters wide at its widest, and the length is determined by the state of the donor. There is also a wide-type dermatome with a width of >10 cm; however, it is not easy to obtain the desired uniform thickness and exact area. The difficulty of handling this instrument can cause irregular pieces of skin and sometimes shortened donor skin piece. Although it is used in the management of major burns, its usage is not commonly recommended.

For the collection of split-thickness skin, when possible, the assistant should pull in the same direction as the dermatome, in the up and down direction rather than side to side. The tension control must not be too strong nor too weak, to maintain evenly distributed tension force, and the collector should collect slowly at a constant speed by adjusting the angle of the blade, pressing force, and side-to-side balance in the direction in which the dermatome is collected.

In particular, in curved areas including the buttocks, the progress speed should be reduced while controlling the balance level between the side-to-side movement, considering and checking for the full estimate width throughout. Commonly donor skin is removed from visible areas such as lateral thigh regions to be time efficient; however, scars and hyperpigmentations from these areas can have an negative psychophysical trauma on the patient because of its unsightly look. Dermatome hand skills require much effort to obtain the desired location, size, and thickness, so the author hopes that this skill can be achieved through persistent practice. Meanwhile, when selecting donor site locations,

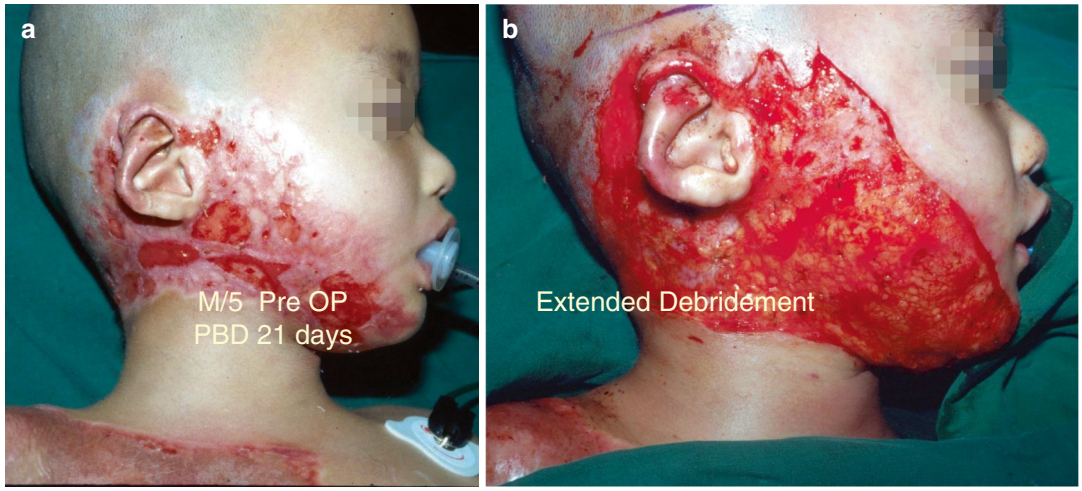

Fig. 1.9 (**a**) Unstable granulation tissue and incomplete epithelialization were noted post-burn day 21. (**b**) The incompletely healed wound bed was debrided with total removal of the granulation tissue and dirty epithelialized area to make single-sheet scalp skin graft

areas that are conspicuously exposed should be avoided to be considerate of the patients, so that the patient can later wear short sleeve tops and bottoms. Acquisition of the dermatome technique is a very important factor in the success or failure in the later part, Chap. 5 Esthetic Skin Graft ("Dermabrasion and dermal resurfacing over-grafting technique"), and the author hopes that hard and consistent efforts will be undertaken toward achieving these skills.

1.3.2 Donor Harvesting on Specific Regions

Scalp donor site is a region where one can obtain skin grafts that are of particular importance for the face of severe burn patients. However, it is very difficult to obtain a large piece of skin graft from a hard and three-dimensionally round head, thereby requiring a special manipulation.

One tip of the maximal size of skin harvesting method is to inject normal saline solution into the loose areolar space of the scalp using an 18–21-gauge needle and a 50-cc syringe on both sides of the flat, parietal area and on both sides of the round, rigid frontal and occipital area. Once the space is inflated and the area is smoothed and flattened out, a wider slice of single sheet of the skin can be sampled. Large amounts of saline (up to 200 cc) can be injected for both children and adults, as the saline is absorbed eventually without problems. The thickness of the skin graft should not exceed 0.25 mm (10/1000 inches) for children and 0.3 mm (12/1000 inches) for adults to allow safe collection without damaging the hair follicle. This is the thickness in which the skin graft can be collected without postoperative alopecia, even after a second sampling, if necessary [29–31].

Furthermore, single-sheet scalp skin grafts produce esthetically pleasing results. In this case, a single-sheet scalp skin graft was used to demonstrate how an esthetic outcome can be obtained (Fig. 1.9). The scalp skin color matches the facial skin color, and there is no donor site morbidity. The harvested thickness and length were 0.254 mm and 9.5 × 20 cm, respectively, and a saline injection was administered to the loose areolar space. The author prefers scalp skin selec-

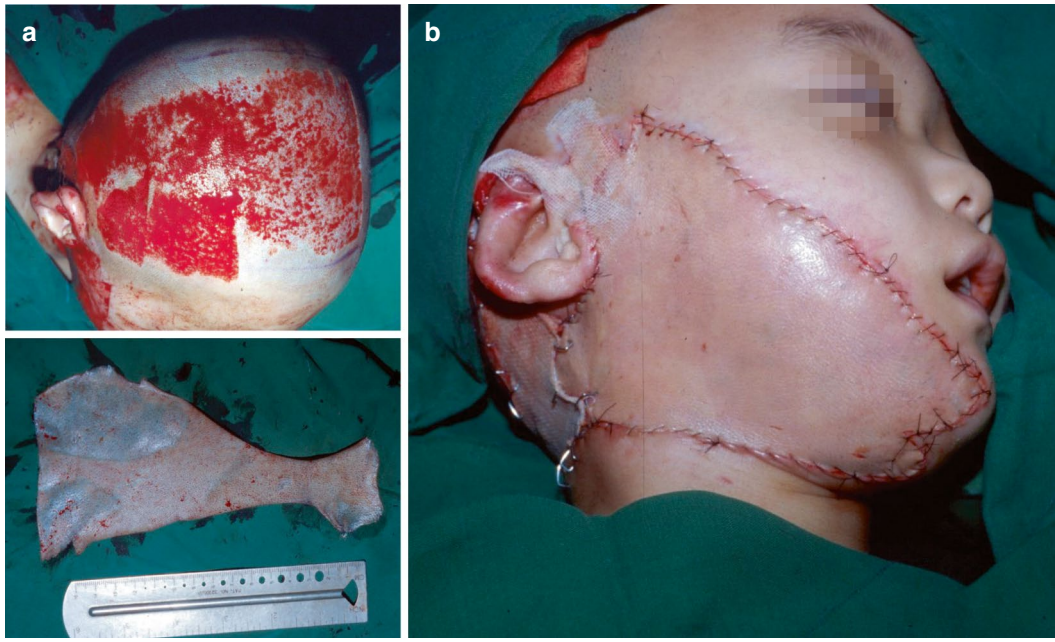

Fig. 1.10 (**a**) The harvested thickness and length were 0.254 mm and 9.5 x 20 cm. (**b**) Single-sheet graft was observed to maximize esthetic outcome without unsightly seam line

tion with a good color match to the face and can make large single sheets using the above scalp injection technique. A single-sheet graft was observed to maximize the esthetic outcome while avoiding unsightly seam lines (Fig. 1.10). Good color matching and good skin texture were observed 2 and 4 years after surgery. Ten years after the operation, there was no disfigurement of the face despite rapid growth. This patient did not undergo corrective surgery and refused additional surgery even after 16 years of adulthood. Note the whitish discoloration on the engrafted boundary due to reflected light, but this minor color mismatch was no longer an esthetic problem for him (Fig. 1.11).

When grafting on the face, recommendation point may divide the esthetic unit which's common sense in plastic surgeons. However, in the author's experience, dividing the esthetic unit is ineffective during the acute phase, so I would strongly advise using a large, single sheet of scalp-donor skin as soon as possible (Fig. 1.12).

When scalp-donor skin is unavailable, skin donor can be obtained from body areas such as the chest; however, if the patient is skinny with apparent sternum and ribs, the skin donor can be infused with IV to inflate the surrounding tissues, smoothing and flattening the area for the collection.

In the abdomen, it is difficult to obtain tension from pulling the tissue tightly side to side; however, if the tension is adequately maintained with the cooperation of assistants, it is possible to obtain a large single sheet of skin graft from this area, easier and larger than one would assume.

If the donor site skin is not properly harvested, (a) you can harvest the anterior chest area with a normal saline injection to flatten the irregular donor sites (black arrow). The abdominal area is also a good donor if well-cooperative supporters apply side to side even tension pressure (yellow arrow) (b). These harvested skin sections were taken from the anterior chest and abdomen and measured 10 × 23 cm each. The thickness was 0.2 mm for the full-face reconstruction with dermabrasion and dermal resurfacing techniques (Fig. 1.13). Note the clinical procedure in Chap. 5: Esthetic Skin Graft (Figs. 1.24, 1.25, 1.26, and 1.27).

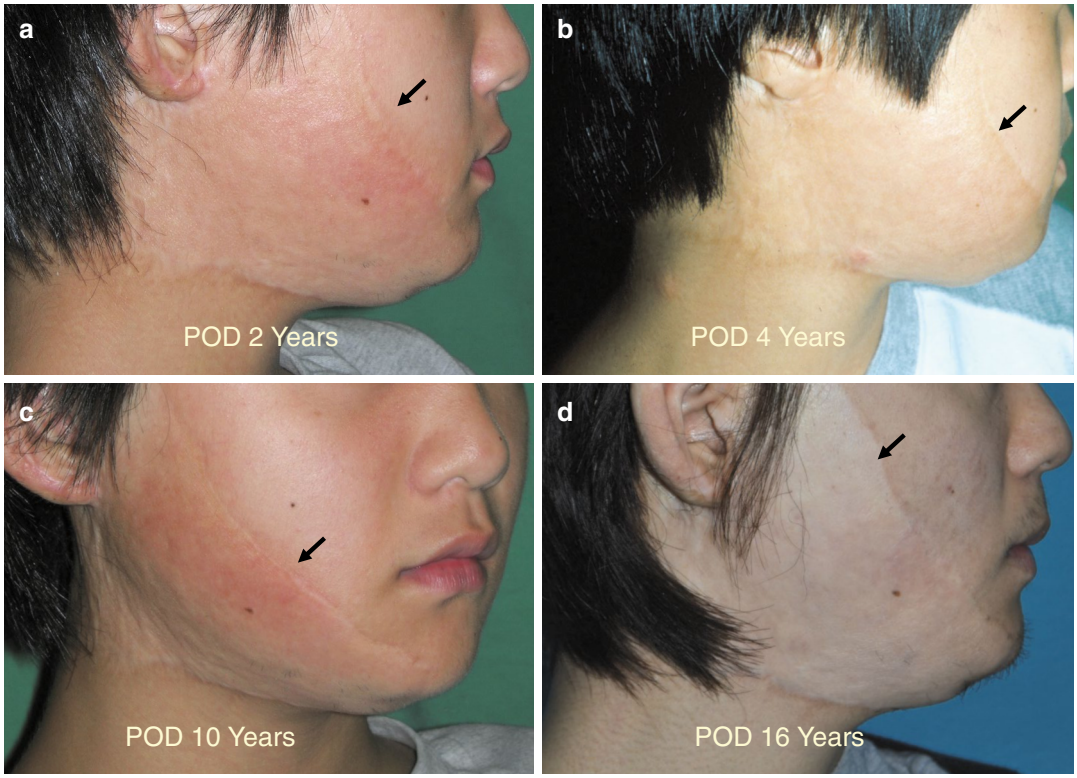

Fig. 1.11 (**a**, **b**) Postoperative view 2 and 4 years after. Focus on the very good color matching and good skin texture. (**c**) Postoperative 10 years after, there was no disfigurement of the face according to rapid growing age. (**d**) Postoperative 16 years after view

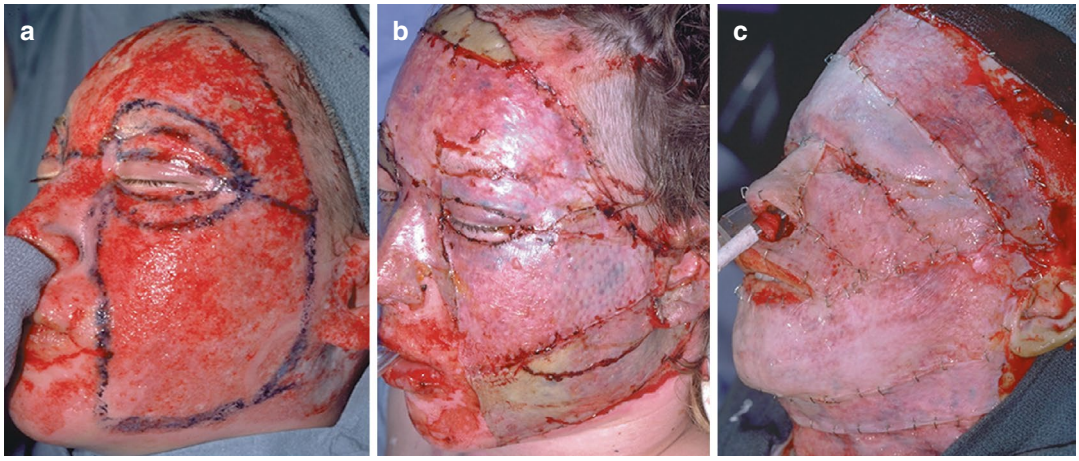

Fig. 1.12 (**a**, **b**) Grafting was performed by dividing esthetic unit on face. (**c**) Dividing esthetic unit is not meaningful in the acute phase in my experiences

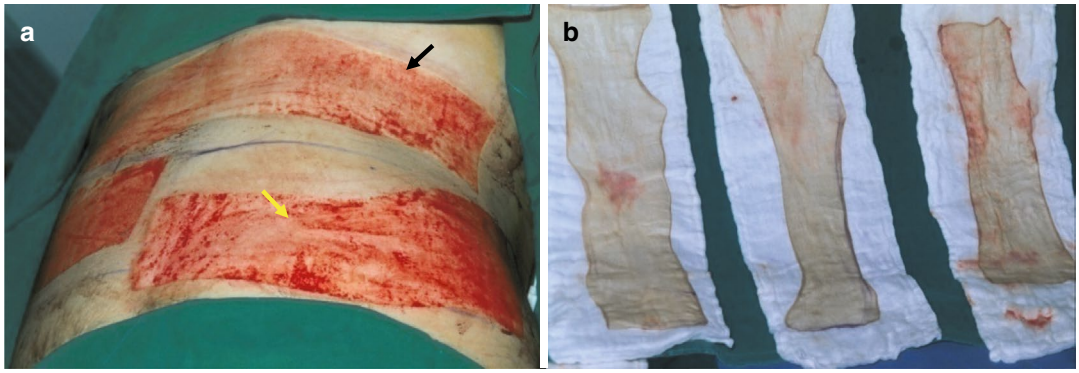

Fig. 1.13 (**a**) Anterior chest and abdomen area are also good donor sites, if using normal saline injection which flatten the irregular donor sites (black arrow). The abdomen is also a good donor if assistants cooperate well (yellow arrow). (**b**) Note three big single sheets measured 10 cm × 23 cm each; thickness was 8/1000 inch (0.2 mm) Note the clinical process on Chap. 5 Esthetic Skin Graft at (Figs. 1.24, 1.25, 1.26, and 1.27)

1.4 General Consideration of Skin Grafts

1.4.1 Conditions for Successful Skin Graft Procedure

Owing to the fact that most factors affecting a successful skin transplantation are related to local issues rather than systematic causes, efforts should be undertaken to frequently check and solve problems that are easily overlooked.

1.4.2 General Condition of the Patient

1.4.2.1 Children and Old Age

- Children: cooperation of treatment, thin skin, nutrition, tendency of hypertrophic scarring.
- Old age: mental status, nutrition, thin skin, cooperation of treatment.
- Obtaining a sufficient graft area in children and old ages is difficult owing to issues related to treatment cooperation and skin thickness. Furthermore, children are prone to hypertrophic scars; it is important to consider the thickness of the graft when selecting donor sites and donor skin.

1.4.2.2 Condition of the Recipient Site

- Inadequate escharectomy is a major cause for concern when performing early excision and early graft; furthermore, tangential excision is performed while observing the pinpoint bleeding pattern. Therefore, if necrotic tissue remains in the wound bed, it can cause graft failure. The surgeon needs to acquire a considerable amount of experience to determine the escharectomy level, accurately remove the necrotic tissue, and create an environment in which the graft can affix to the healthy wound bed. Some surgeons believe that the fat layers interfere with the skin graft taken; however, the author believes that these layers aid the healing process. Therefore preservation of fat layers is highly recommended.
- After the necrotic tissue or eschar is removed, a healthy granulation tissue bed should be formed on the wound bed.
- Infection control: check for infection with *Staphylococcus*, *Streptococcus*, methicillin-resistant *Staphylococcus aureus (MRSA)*, *Pseudomonas*, etc., among others, in particular.
- Immobilization.
  Splint, tie overdressing, and K-wire.
  By immobilizing the engrafted skin using a punched-out silicone sheet (Mepitel™), the engraft skin itself can be fixed and safely protected until it has taken.
- Operation site and position of the graft site.
  The take rate of the skin graft may vary depending on the posture or position maintained by the patient. In particular, the face, neck, groin, buttocks, armpits, and back are

places where it is difficult to maintain posture during engraftment. Using a splint or vacuum assistant (VAC) system allows for a more convenient and safe management.

1.4.3 Factors Causing Graft Failure

1.4.3.1 Wound Bed Environment

There are higher chances of graft failures when escharetomy is perforemed too early for deep second- or third-degree burns, when deep burns are present, and when viable and nonviable tissues are difficult to distinguish and an inappropriate resection is performed.

1.4.3.2 Fluid Collection (Hematoma, Seroma)

Graft loss is most often caused by hematoma. The main causes of graft loss are inadequate escharectomy and bleeding control. The main postoperative cause is the insufficient immobilization and protection of the operative site. Therefore, it is necessary for the surgeon to be skilled and provide systematic management for bleeding control in the operation field. In most cases, the author only uses epinephrine injection for bleeding control and does not use electrocauterization or tourniquets. Although this method is not easily acceptable, it critically affects the success or failure of the operation and thus will be introduced in further detail in Chap. 2.

1.4.3.3 Infection

Graft loss due to systemic infection caused by wound sepsis is currently rare, and the most common cause is local pathogens.

Most of the criteria for infection are obtained by performing local bacterial culture and strain culture, but it cannot be said that the results of these cultures are accurate. The surgeon's judgment is more important. The early excision and early grafting before bacterial colonization forms results in a higher graft take rate.

1.4.3.4 Immobilization

Restricting the movement of the graft site has a very important effect on the graft take. Therefore, it is important to maintain immobilization until the graft is taken. Appropriate measures include using a splint or Surgifix®, tie-over dressing, and the VAC system to restrict movement for a certain period of time in the face, neck, waist, large joints, and hips [32, 33].

In this section, rather than discussing STSG anew, as it is quite common, the author will introduce STSG in acute facial burn management, which still has many controversies, and ectropion correction, which always becomes controversial in cases of facial reconstructive surgery.

1.5 Management of Facial Burn

In this chapter, the author will describe the importance of the decision making and time management for surgeries, to reduce reconstructive surgeries later on.

Followings are the main issues regarding facial burn treatments:

- Debates include the availability and timing of surgery for acute burns.
- Selection of partial- or full-thickness grafts for the upper and lower eyelids in reconstructive surgery of ectropion.
- Selection of skin grafting method for reconstruction of the surrounding tissue of the eyes, nose, mouth, ears, and so forth of the face.

1.5.1 Management of Acute Facial Burn

Early treatment of facial burns is very important and has the greatest influence on the patient's life. In other words, appropriate response to the initial treatment has a profound effect on not only the patient's functional recovery but also their mental suffering and social life [34–36]. Therefore, treatment that is professional and conducive to wound healing should be prioritized. In general, when treating patients with severe burns that endanger their lives, the best efforts should be focused on saving the patients' lives first. However, if facial burns are present and the initial treatment is not appropriate, serious problems may occur subsequently [37, 38]. Therefore, a cooperative treatment system that treats burns with systematic

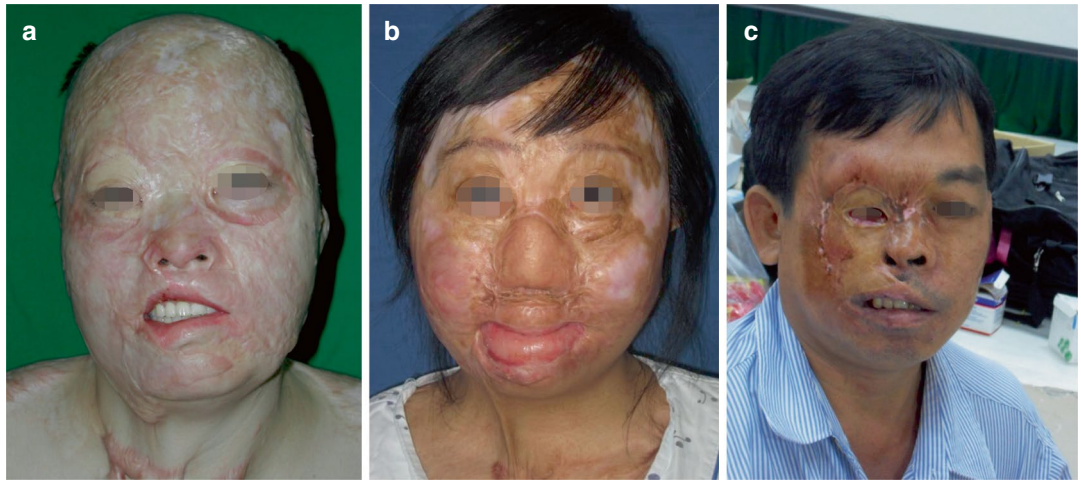

Fig. 1.14 These patients are well shown on how many difficult and serious deformities remained and they need multitudinous corrective surgeries

treatment as well as plastic surgery is essential [39]. Considering this, establishing an intimate cooperation system with specialized departments, such as plastic surgery, respiratory internal medicine, ophthalmology, otolaryngology, and orthopedic surgery, for the treatment of patients with severe burns is a very important task in the future.

These patients' cases demonstrate the critical importance of initial proper wound management in acute facial burns.

A 33-year-old woman suffered a flame burn and was treated at another department. Three years after the burn incident, she received conventional wound dressing for more than a month, a partial patch and mesh skin graft were applied to the unhealed sites. One year after the burn incident, she received FTSG to correct both upper and lower ectropion. Notice the unnatural appearance and undercorrection of both upper and lower eyelid ectropion.

A 21-year-old woman suffered a flame burn, had a total burn surface area (TBSA) of 70%, and underwent over 15 operations. This patient had an improper skin graft on the dorsum of the nose and perioral area as well as undercorrected ectropion of both lower lids. This female patient underwent reconstructive surgery on her right face three times. Note the undercorrection and disfigurement of the upper lip and nose as well as the upper and lower lid ectropion.

These patients clearly demonstrate the importance of proper initial management of burned faces and the number of corrective surgeries (Fig. 1.14).

Generally, because of the face's good blood circulation, thin skin, and good elasticity, it is easy to think that the face will respond well to burn treatment and heal well without severe scars. But for severe facial burns, meticulous management must be undertaken to avoid future facial deformity. In cases with female patients with good skin elasticity, male bearded areas, infants, children, or those with a family history of hypertrophic scarring, severe hypertrophic scarring often develops after approximately 3–6 months of burn healing. Regular periodic follow-ups and skin care programs are recommended for at least 3–6 months or over 1 year [40].

For mild second-degree burns caused by general fire or hot water, frequent usage of (once or twice per day) mask pack with a cold compress effect, a moist gauze, or a Burn Shield (Hillegom, Netherlands) is used. After the swelling and pain subside within 2–3 days, use a dressing material that can promote epithelialization. At this time, one must be careful to remove the exudate by popping the blisters if possible, but try to obtain the effect of a biological dressing by preserving the separated epidermis as much as possible. If the separate epidermis is removed, it is better to

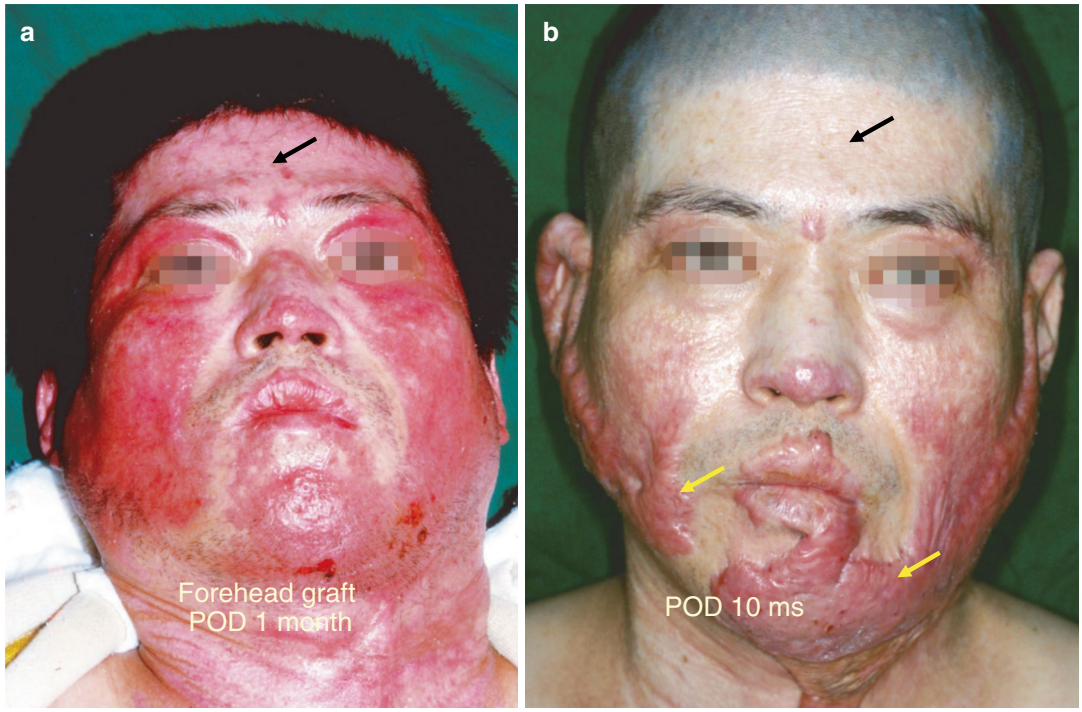

Fig. 1.15 (**a**) Postoperative 1 month view, engrafted forehead with scalp skin noted good graft taken and compared with conservative managed sites; the redness developed with mild elevated hypertrophic scarring on both the upper and lower bearded areas. (**b**) Postoperative 10 months after, severe hypertrophic scar developed on bearded area (yellow arrows)

use a cell therapy such as CEH that can replace the epidermis, to accelerate epithelialization, and shorten the treatment period. Second-degree burns with deep burns require a more careful treatment and judgment.

Most of the second-degree burns of superficial or mild thickness can be healed within 2 weeks. After healing, the pores become slightly deeper and wider than normal, and there is a hint of rough skin discoloration or hyperpigmentation. These findings start to appear gradually after approximately 3 months, and in the case of sensitive skin or children, a bright red rash and weak hypertrophic scars may be observed. Therefore, it is recommended to continue meticulous skin care for at least 3 months and, if necessary, to use laser treatment or a medical skin care unit to minimize the redness [41]. The patient should also be educated regarding the avoidance of exposure to ultraviolet light. However, even with medium-grade second-degree burns, if a male's beard area is not treated appropriately, it may develop into a surprisingly serious hypertrophic scar. This is a well-shown case mentioned.

A 42-year-old male patient suffered a flame burn with a TBSA of 30%. A scalp-donor STSG was performed on day 19 of the burn on the forehead only because the other facial sites were almost healed. (a) One month after surgery, the engrafted forehead and other sites healed into mild, elevated, and developing hypertrophic scarring on both the upper and lower bearded areas. (b) Ten months after, engrafted forehead area had good color match and texture (black arrow), but a severe hypertrophic scar developed in the bearded area (yellow arrows). Decision of time management of the surgery is very important to avoid hypertrophic scarring sites, which is presented here on the bearded areas, cheeks, and mentum

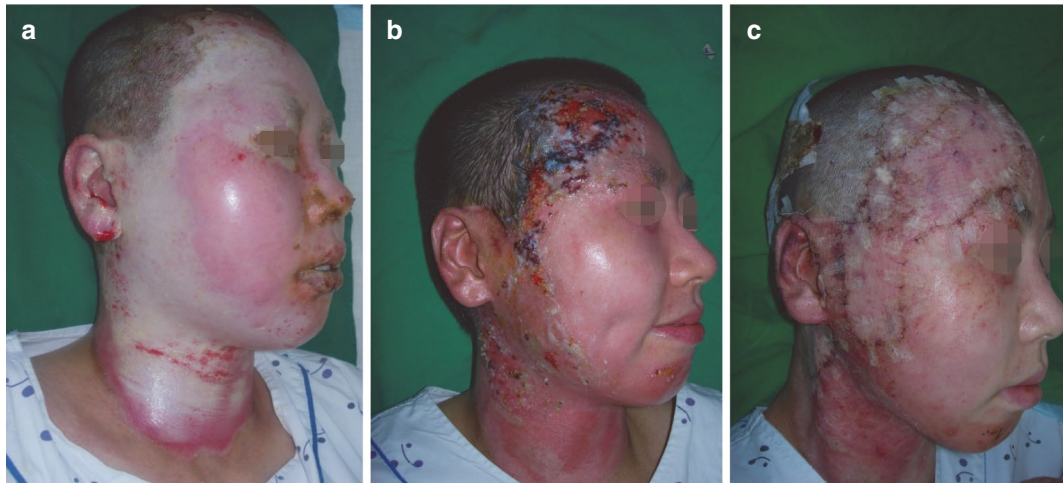

Fig. 1.16 (**a**) Deep second-degree burn on the forehead, cheek, and neck areas, (**b**, **c**) Post-burn 4 weeks, 12/1000-inch thickness scalp skin graft was performed on the forehead and right temple area

areas (Fig. 1.15). It is always important to ensure the patient is aware of the possibility of the development of hypertrophic scarring and to provide continuous management.

More than 2 weeks of treatment is required in most cases of deep second-degree burn, and in some cases, over 4 weeks is commonly needed. Controversies surrounding the variable treatment method and window is often misssed by confusion of deciding the extension area of the surgery.

A 28-year-old female patient was injured by an air balloon gas explosion on the right side of the face, resulting in a deep second-degree burn on the forehead, cheek, and neck. Four weeks after the burn incident, dirty granulation tissue remained in the unhealed wound. On the forehead and right temple area, a 0.3-mm-thick scalp skin graft was performed. However, conservative wound dressing had already healed the right cheek and neck (Fig. 1.16). Six months after the burn incident, a hypertrophic scar developed gradually. One year later, the hypertrophic scar markedly developed, and flap surgery using tissue expander method was performed. Two years after the operation, a marginal hypertrophic scar had developed on the tissue expander flap surgery margin. Observe and compare the forehead, temple, and right cheek (black arrows), which had received an earlier skin graft and conservative wound dressing. This case demonstrated the importance of early excision and skin grafting on the burned face, which resulted in a significantly different end result and necessitated considerable effort (Fig. 1.17).

In the author's case, clinical findings based on the depth of the burn are the most important criterion; however, if there are no signs of healing process after >2–3 weeks, a skin graft using scalp skin as a donor is performed.

A 36-year-old male patient suffered a flame burn with deep second-degree burns. Two weeks after the burn incident, an early excision and scalp skin graft with 0.3-mm-thick scalp skin were performed. Note the excluded area on the brow area to preserve the hair follicles. Four months after surgery, excellent results were observed with no hypertrophic scarring and well-preserved eyebrows (Figs. 1.18 and 1.19).

On day 16 after the burn incident, a 42-year-old patient underwent a scalp-donor skin graft. One year after the burn incident, the forehead and left cheek showed excellent results with good color matching and texture, and the engrafted seam line was not visible. However, in the mustache area, a hypertrophic scar developed, which was healed with early epithelialization (Fig. 1.20).

Fig. 1.17 (**a**, **b**) Post-burn 6 months and 1 year after view, hypertrophic scarring developed on the previously conservative treatment area. (**c**) Postoperative 2 years later view, note and compare forehead, cheek, and right mentum (black arrows) which received early scalp skin graft and conservative wound dressing on the right mentum

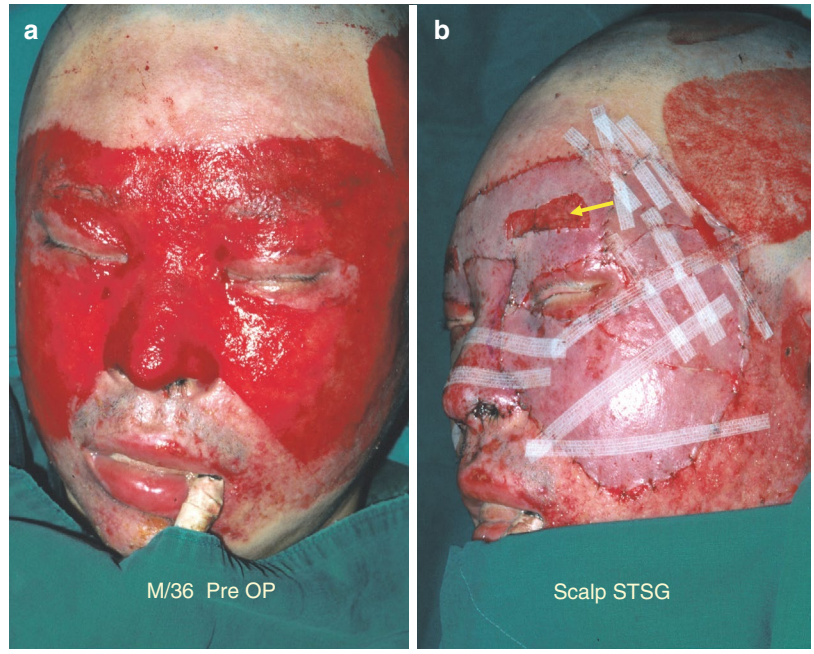

Fig. 1.18 (**a**) Early excision and scalp skin graft was performed post-burn 2 weeks with 12/1000-inch thickness scalp skin. (**b**) Note the excluded area on eyebrow area to preserve hair follicles (yellow arrow)

These cases demonstrated that scalp-donor skin achieved excellent esthetic results, which is the author's preferred donor skin for acute facial burn management.

In the author's case, even for severe flame burns, explosive burns, or even third-degree burns caused by chemical burns, the time of surgery is set at 3 weeks to ensure a chance of preservation of even a little viable tissue; however, in the absence of any signs of wound healing process, a skin graft is performed as soon as possible. The STSG was set as the base surgical method for acute facial burns, and as an important donor site, scalp skin thickness should not exceed 0.3 mm (0.25 mm for children), but if the scalp skin is not available, one may use the usual donor skin. Recently, the author prefers to use a large single-sheet graft than smaller esthetic units in acute burn stage (Figs. 1.7, 1.8, 1.21). The use of artificial dermis, which has recently been

Fig. 1.19 Postoperative 4 months later, excellent result was observed with no hypertrophic scarring and well-preserved eyebrow hairs

Fig. 1.20 (**a**) Post-burn day 16, 0.3-mm-thickness scalp skin graft was performed. (**b**) Post-burn 1 year later view, the forehead and left cheek area was noted excellent outcome with good color matching and texture (black arrow). Left alar and mustache area noted hypertrophic scar development in which this area was healed with early epithelialization (yellow arrows)

increasing, is not used in the facial area unless serious defects are present owing to third-degree burns. This is because the wound healing process of the facial area is very fast and has good resilience. This area is also thin, and thick scars caused by the artificial dermis leave an unnatural scar bed for reconstructive surgery and are not preferred because of the heavy cost.

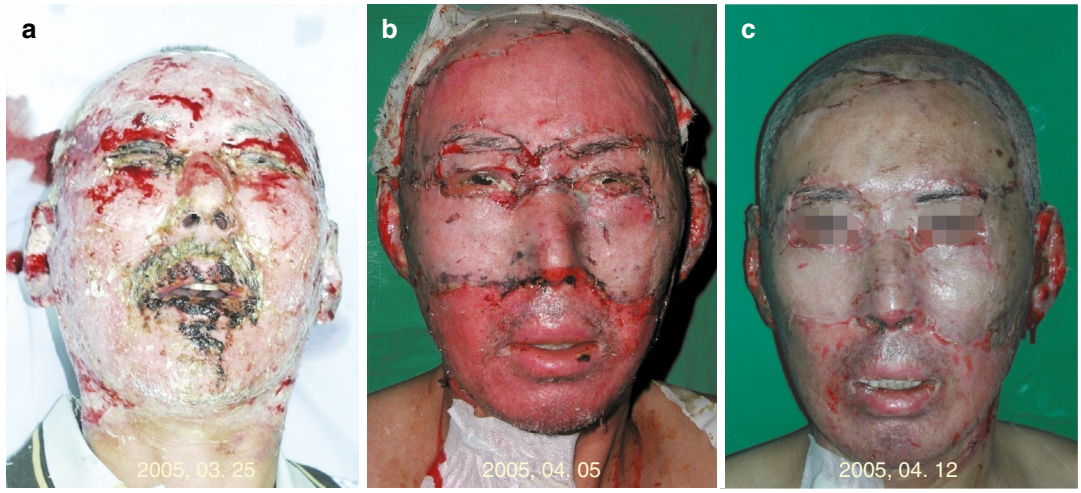

Fig. 1.21 (**a**) Post-burn day 17, early excision and early skin graft were performed with scalp skin. (**b**) Postoperative 7 days, engrafted upper, lower lid area and forehead grafts were successfully taken. (**c**) Postoperative 2 weeks after, mild ectropion had developed both lower lids

Areas to pay attention to when performing STSG are the upper and lower eyelids, eyebrows, places with a great distribution of hair follicles such as beard areas in men, and areas of cartilage such as the ears and the nose. To reduce the risk of chondritis in the ear or the nose cartilage area, timely STSG is important to prevent partial or total loss caused by chondritis; if there is an edematous and inflammatory change or sign of infections, surgery must be performed within 3 weeks.

A 53-year-old male patient suffered flame burns on his full face with deep second- and third-degree burns. Seventeen days after the burn incident, an early excision and early graft were performed using scalp skin. Seven days after surgery, the upper and lower lids, as well as the forehead area, were found to be completely grafted. Two weeks after the operation, mild ectropion had developed on the upper and lower lids. In addition, ear burns must be grafted early to prevent suppurative chondritis and ear loss (Fig. 1.21).

A 21-year-old male patient was attacked with strong sulfuric acid on the right side of his face. Eight days after the burn incident, an escharectomy was performed, and the wound was covered with a fresh cadaver allograft to preserve viable tissue and promote wound healing. After 2 weeks, the allograft was removed, and an AlloDerm® skin graft with a thickness of 0.15 mm was performed on the entire ear, right cheek, and neck. In this case, scalp skin was not used because the scalp was also injured caused by the chemical burn. Fifty-five days after the burn incident, note the well-preserved shape of the ear and the good healing on the right cheek and neck, with no scar contracture. In this case, even a strong-acid chemical injury should be treated with proper wound management and early skin graft to achieve a higher-quality outcome. I strongly recommend these wound management techniques for the treatment of chemical attack burns in order to prevent severe disfigurement deformities, which is a serious social issue in many Asian countries (Figs. 1.22 and 1.23).

In the eyebrow or beard areas, hair follicles are preserved as much as possible by refraining from grafting; however, in some cases, severe hypertrophic scarring on the mustache or beard progresses (Fig. 1.18), and the frequent occurrence of folliculitis makes the treatment difficult. Therefore, individual opinions may differ regarding the need for skin grafting, but the author's personal opinion is to place greater emphasis on the preservation of men's natural beards or eyebrows if possible. In addition, to reduce the frequency of hypertrophic scars and folliculitis in the early stages after burn treatment by refraining from skin grafting, efforts are made to obtain good results by using a combination of auxiliary therapies such as laser, pressure garment, silicone gel sheet, and steroid therapies. However, it is difficult to establish a definitive

Fig. 1.22 (**a**) Patient was attacked sulfuric acid on the right face, (**b**) post-burn day 8 escharectomy and covered with flesh cadaver skin. (**c**) After 2 weeks, allograft was removed and AlloDerm with 6/1000-inch thickness skin graft was performed including the total ear, right cheek, and neck area

Fig. 1.23 Post-burn 55 days after, note the well-preserved total ear shape and good healing state on the right cheek and neck area

guideline because of the frequent development of hypertrophic scarring and consistent folliculitis, both of which are hard to resolve because it all depends on the individual patient.

In the case of upper and lower eyelids, the skin is the thinnest and heals well; thus, if possible, cell therapy CEH is used to induce natural healing. However, in the case of loss of the entire eyelid skin layer, 0.2 mm-thick STSG or 0.25 mm scalp skin is performed, and where possible, if a larger sufficient skin graft area is secured, more natural and good color matching can be obtained.

A 55-year-old female patient suffered flame burns on her face. Twelve days after the burn