Natural Reconstruction: A Comprehensive Standardized Operating Procedure for Restoring Eyebrow Loss Due to Scarring

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carring-associated hair loss in eyebrows, usually caused by severe burns, trauma, tumor resection, local flap formation, or tattooing, has negative physical and psychological effects on patients. Absent eyebrows are usually restored by a superficial temporal artery island scalp flap,
composite skin graft, and hair transplantation. Use of a superficial temporal artery island scalp flap has several drawbacks, in that the restored hair is denser and thicker than before scarring, having a brush-like appearance with sharp boundaries. In addition, these procedures require extensive dissection, which is complex and time-consuming. This method has therefore been recommended for the reconstruction of male, but not female, eyebrows. Furthermore, these methods often result in unfavorable outcomes, including scarring and new defects. Hair transplantation can overcome these drawbacks, possibly producing more natural eyebrows with optimal hair density and proper orientation, with methods based on follicular unit transplantation and follicular unit extraction techniques resulting in patient satisfaction. In contrast to follicular unit transplantation, follicular unit extraction involves the direct extraction from donor sites of hair grafts that match the color and diameter of the original eyebrow, without scarring. Although combination of follicular unit extraction and prosthesis implantation in a patient with eyebrow and orbital defects attributable to burst injury resulted in patient satisfaction, the study lacked long-term follow-up data. In addition, leg hairs obtained by follicular unit extraction have been used to thicken the density of sparse eyebrows. We have assessed the ability of hair grafts extracted from the hairline or frontal-temporal triangle and divided into single-hair grafts to restore eyebrows in patients with partially lost or sparse eyebrows. We found that this method of eyebrow restoration achieved better results than follicular unit grafting, as determined by patient satisfaction with survival rate and natural appearance.

Eyebrow restoration, including attainment of ideal shape and appearance, is more difficult in patients with eyebrow absence attributable to scarring, owing to poor blood supply and stiffness. Moreover, the direction in which hairs must be transplanted changes frequently in different situations. Hair transplantation in these patients requires fully evaluating scar quality and balancing ideal eyebrow density and sufficient blood supply at recipient sites. We have focused on methods of restoring these scarred eyebrows to their original appearance and maximizing graft survival rate. Based on our experience, postoperative follow-up, and evaluation of its effect, we have developed a comprehensive standardized operating procedure for restoration of complete unilateral and bilateral eyebrow defects.

**METHODS**

**Standardized Operating Procedure**

**Evaluation of Scar Properties**

Subjective and objective evaluations of scar properties are essential before reconstruction. Subjective evaluations of scar quality include visual, sensory, and tactile assessments. Visual assessments include scar color, height, and surface appearance, whereas sensory assessments include itching and pain, which represent scar instability. In general, mature scars are pale, flat, soft, and nontender, whereas immature scars are red, stiff, itchy, painful, and at a level above surrounding tissue. Tactile assessments include pliability and elasticity, with good pliability regarded as smooth movements of scars in various directions and good elasticity as the scar being more than 50 percent of the height of surrounding healthy tissue. Objective evaluations include assessments of blood supply, performed by puncturing subcutaneous tissue with a needle and determining whether bleeding occurs. Two other objective methods are available to evaluate blood supply. The first, a trichoscopy device, which is portable and noninvasive, evaluates capillary structure through optic magnification and can also be used to distinguish hypertrophic scars from keloids. The other method is the capillary filling test. Scars suitable for hair implantation must be in a stable state with certain elasticity and pliability, as well as adequate vascularity to ensure graft survival.

**Inclusion and Exclusion Criteria**

Patients were included if (1) they had different degrees of eyebrow defects attributable to scar formation; (2) the scar was in a stable state, ideally with some subcutaneous tissue, and pliable; (3) there was no obvious infection or inflammation; and (4) the blood supply in the recipient bed was sufficient. Patients were excluded if (1) they had keloid scars; (2) the scars were close to or directly attached to bone; (3) donor hairs were tightly curled or of a thicker caliber than before scarring; (4) they had psychological abnormalities; (5) they were unable to accept regular eyebrow trimming; or (6) they had uncontrolled hypertension and/or hyperglycemia.

**Donor Area Assessment and Management**

Hair donor areas included the lower occipital hairline adjoining the neck, the posterior auricular hairline area, and the frontal-temporal triangle area, as hairs in these regions are soft and
thin. Before surgery, hair caliber in the original eyebrow and in these three candidate donor areas was measured by trichoscopy, and the area with hair diameter closest to that of the original eyebrow was selected. If the hairs in all three areas were of similar diameter, the lower occipital and posterior auricular hairlines were preferred to the frontal-temporal triangle area. If the entire eyebrow had been lost, the area with hair diameter of 0.04 to 0.08 mm was chosen. Donor hairs were trimmed to a length of 3 to 5 mm before grafting to obtain a better immediate postoperative effect and estimate the long-term postoperative effect.

Graft Preparation
Hair grafts were harvested through the follicular unit extraction technique with a 1.5 or 2.5 loupe that minimized transection. Follicular unit extraction hollow needles with an outer diameter of 1.0 mm were recommended for unskilled physicians, whereas needles of 0.8 mm and 0.9 mm diameter were recommended for experienced physicians. These needles were able to extract hair grafts in the direction of hair growth at a speed of 3500 to 4000 rpm. Thinner grafts consisting of follicles containing one or two hairs were selected, with the number of hairs harvested being dependent on the hair density of the original area or the shape of the redesigned area.

Hair Follicle Preservation and Refinement
The harvested hair grafts were stored immediately at 0 to 4°C in Ringer solution for no more than 2 hours. Storage in platelet-rich plasma or serum may also help preserve hair cells and avoid ischemia–reperfusion injury after implantation. The grafts were placed on a tongue depressor and dissected into single hair follicles (Fig. 1) using a surgical knife with a number 11 round blade parallel to the hair shaft to avoid follicular transection. These procedures were performed under stereomicroscope. Any superfluous epithelium or subcutaneous fat was removed. Grafts were divided into three types: vellus hair, thin hair, and mediate hair (Fig. 1). In addition, damaged hair follicles, including those with partial or complete shaft transaction, were discarded, as were grafts with an impaired hair bulb or bulge region (Fig. 2).

Eyebrow Design
In patients with unilateral eyebrow defects, the reconstructed eyebrow was shaped similar to that of the contralateral intact eyebrow (Figs. 3 and 4). In patients with bilateral eyebrow defects, reconstruction of new eyebrows had to consider the facial symmetry of each individual (Figs. 5 and 6). In men, eyebrows are generally uniform and flat and are designated sword eyebrows. Arches are higher in women than in men. Generally, the widths of eyebrow peaks are approximately 1 cm in men and 0.8 cm in women, and the lengths and widths of eyebrows are 5.5 cm and 0.8 cm, respectively, in men and 5 cm and 0.6 cm, respectively, in women. Most eyebrow shapes in the current study were designed to be similar to the Anastasia style. Previous studies have also noted that Anastasia was the most preferred shape among patients of different ages and occupations. The medial end extended vertically through the nostrils, the arch was on a line drawn from the center of the nose through the center of the pupil, and the line between the lateral end of the eyebrow and the edge of the corresponding nasal ala ran through the lateral canthus (Figs. 7 and 8). The distance from the midpupil to the top of the eyebrow was 2 to 2.5 cm. Although the head, tail, and peak position of the eyebrow were designed based on these parameters and reference lines, these measures and lines were not fixed and were adjusted based on personal preferences and face shape. Five basic eyebrow shapes have been identified, including curved, sharp angled, soft angled, rounded, and flat eyebrows. In general, sharp angled eyebrows are preferred.
for individuals with round faces, rounded eyebrows for people with heart-shaped faces, and flat eyebrows for individuals with long faces. All eyebrow shapes are suitable for people with an oval face. The designed eyebrow outline was marked on the patient’s face using methylene blue.

**Recipient Site Anesthesia**  
Patients were shifted from the prone to the supine position and their faces were washed three times with chlorhexidine. The recipient site was anesthetized locally by slowly injecting a solution containing 2% lidocaine and 0.1% epinephrine.

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**Fig. 2.** Grafts needing to be discarded included (from left to right) ones with (left) graft transection, (second image) damaged bulge area, (third and fourth images) dermal sheath damage, (fifth image) crush injury of hair follicle (green) or dermal sheath damage (red), or (right) hair in poor quality.

**Fig. 3.** Outcomes in a 22-year-old man with partial right eyebrow loss attributable to skin grafting following tumor excision 2 years earlier (left). The right eyebrow was restored with 237 single-hair follicles. To ensure consistent appearance of both eyebrows, 169 single-hair follicles were implanted into his left eyebrow. Six months later (right), the reconstructed eyebrow presented a bionic appearance.
subcutaneously into the superficial dermis using a 1 ml syringe and 32-gauge needle. Higher concentrations of epinephrine were administered as necessary to reduce intraoperative bleeding and avoid bruising. After injection, proper pressure and an ice compress were applied for 5 minutes to promote infiltration of anesthetic. Each injected area was no more than 1.5 ml in volume.

Fig. 4. Outcomes in a 20-year-old woman with partial left eyebrow loss attributable to trauma from a car accident 3 months earlier (left). Her left eyebrow was restored with 192 single-hair follicles. To ensure consistent appearance of both eyebrows, 167 single-hair follicles were implanted into her right eyebrow. Seven months later (right), the reconstructed eyebrows had a satisfactory survival rate and a bionic appearance.

Fig. 5. Outcomes in a 39-year-old woman who lost both eyebrows as a result of total brow resection 2 months earlier (left). Her eyebrows were restored with 215 single-hair grafts on the right side and 230 single-hair grafts on the left side. Seven months later (right), her reconstructed eyebrows presented a bionic appearance.

Fig. 6. Outcomes in a 19-year-old man who sustained a facial burn 17 years earlier and underwent skin grafting 1 year earlier, resulting in bilateral eyebrow loss. His eyebrows were restored with 215 single-hair follicles on the right side and 203 single-hair follicles on the left side. After 23 months (right), only one stage showed satisfactory density and a natural appearance.
Graft Implantation

Holes were made in the marked area by punching with a 23-gauge needle at an angle of 5 to 10 degrees, depending on the direction of original hair growth. Other protocols were used in specific patients, as follows. (1) Because the bed in patients with stiff scars is characterized by tight adhesion of skin and muscle, making the
recipient area brittle and easy to split, the micro-
holes should not be too dense. These patients may
therefore require two or more sessions to restore
desired eyebrow density, and the angle between
the needle and skin may require adjustment to
~10 to 20 degrees. (2) Because beds in patients
who previously underwent flap transplantation
are characterized by thicker subcutaneous fat,
reduced tension, and a loose base, it has been re-
commended that the grafts be inserted at a smaller
angle than in normal tissues. Because grafts tend
to spread around and appear to have a low density
after implantation, the density and orientation
may require adjustment 6 months after the opera-
tion. (3) The presence of extensive adhesion scars
in the superciliary arch area may result in a need
to move the upper eyelid upward to the original
eyebrow position. If the bed is characterized by
thin skin with less subcutaneous fat, eyebrow res-
ervation might require graft insertion at a small
angle to the skin near flat. In addition, contract-
ure deformities such as eyelid ectropion should
be released before hair transplantation.

In general, hair grows in different directions.
The head and lower part of the eyebrows were
restored by inserting grafts in the superolateral
direction, whereas the tail and upper part of the
eyebrows were restored by inserting grafts in the
inferolateral direction. Holes were punched to a
depth of about 4 to 5 mm, followed immediately by
placement in the hole of a hair in the same direc-
tion as the extracted needle. Hairs at the margins
were implanted first, followed by filling of the area
with the grafts and adjustment of their density. The
medial area was restored with smaller caliber and
lighter-color hairs, whereas the middle-lateral area
was restored with wider caliber hairs to assure that
they looked denser. Uniform density and symme-
try were optimized relative to the untreated side.

[See Video (online), which demonstrates the eye-
brow reconstruction procedure presented in this
study.] Following surgery, patients assessed their
postoperative appearance and reported whether
they were satisfied with their new eyebrows and
whether they required adjustment.

Postoperative Care

The recipient site was left open and coated
with antibiotic ointment such as chlortetracycline
or mupirocin twice daily for 5 days, protecting
the transplanted hairs from friction. Patients were
allowed to wash their faces as usual after 2 post-
operative days, with washing of the recipient area
following the direction of eyebrow flow. To avoid
tissue swelling, ice compresses could be applied
for 3 to 5 days. Patients were re-examined 7 to 10
days after surgery. Hair length was maintained by
trimming at 5- to 7-day intervals. Graft survival
rates were measured after 6 months.

Outcomes Measures

Postoperative complications were recorded at
7 days. The number of implanted grafts and the
number of surviving grafts after 6 months were
counted and the average graft survival rate was
calculated. Because FACE-Q was considered a
valid method for assessing patient satisfaction with
facial aesthetic procedures,22,23 we assessed patient
satisfaction using a questionnaire based on the
original FACE-Q (Table 1). Procedure-specific
sections were added, except for the generic part.
Patients were asked to complete questionnaires at
6 months postoperatively. To increase the objec-
tivity of the evaluation, three evaluators (a derma-
tologist, a plastic surgeon, and a nurse) compared
photographs taken preoperatively and 6 months
after the operation. Observers and patients rated
items on a visual analogue scale ranging from 0 to
10, with 0 representing high dissatisfaction with

| Questionnaire Items                                               | Answers (score based on VAS) |
|------------------------------------------------------------------|-----------------------------|
| Patient assessments                                              |                             |
| Satisfaction with appearance (natural, covers the scar)          | 0 (very dissatisfied) to 10 (very satisfied) |
| Satisfaction with density                                        | 0 (very dissatisfied) to 10 (very satisfied) |
| Satisfaction with shape                                          | 0 (very dissatisfied) to 10 (very satisfied) |
| Satisfaction with symmetry                                       | 0 (very dissatisfied) to 10 (very satisfied) |
| Satisfaction with decision                                       | 0 (very dissatisfied) to 10 (very satisfied) |
| Social function                                                  | 0 (very dissatisfied) to 10 (very satisfied) |
| Psychological well-being                                         | 0 (very dissatisfied) to 10 (very satisfied) |
| Early life impact                                                | 0 (very dissatisfied) to 10 (very satisfied) |
| Observer assessments                                             |                             |
| Satisfaction with all the appearance (overall evaluation based on
  preoperative and 6-month postoperative photographs)             | 0 (very dissatisfied) to 10 (very satisfied) |
| Observer 1                                                       | 0 (very dissatisfied) to 10 (very satisfied) |
| Observer 2                                                       | 0 (very dissatisfied) to 10 (very satisfied) |
| Observer 3                                                       | 0 (very dissatisfied) to 10 (very satisfied) |
the outcome and 10 representing high satisfaction with the outcome.

RESULTS

From 2012 to 2019, 167 patients with eyebrow defects were admitted to Nan Fang Hospital. These patients included 99 women and 68 men (mean age, 26.43 years; range, 16 to 42 years). Eyebrow defects resulted from scalding burns in 62 patients, trauma in 87, local flap transfer in 12, and skin grafting in six. Sixty-seven patients underwent partial eyebrow reconstruction, 62 underwent unilateral eyebrow reconstruction, and 38 underwent bilateral eyebrow reconstruction (Table 2). Donor sites included the lower occipital area in 90 percent, the posterior auricular area in 10 percent, and the frontal-temporal triangle area in 10 percent. An average of 600 single hair follicles was required for complete eyebrow reconstruction, and the amount was lower in women than in men. The duration of surgery was 2 to 4 hours.

Donor and recipient areas of all patients were well healed, with none having pigmentation around the grafted hairs. Of these 167 patients, 159 were highly satisfied, seven were satisfied, and one was dissatisfied, with none being highly dissatisfied. The mean graft survival rate at recipient sites was 85 percent (range, 70 to 90 percent). Eight patients required a second operation to increase hair density, such that the new eyebrow completely camouflaged the scar. No patient developed hematoma, infection, folliculitis, hemorrhage, or any other complication (Table 3).

DISCUSSION

The eyebrows are a very significant aesthetic feature of the face and are involved in facial expressions. Appropriate eyebrow shape and density are particularly important for facial appearance. Because previous outcomes have not always been satisfactory, with low survival rates and unnatural appearances, transplantation is increasingly used in eyebrow restoration. The current study describes comprehensive operating procedures based on the authors’ experience, improved technology, and surgical skills to achieve good outcomes. This standardized operating procedure resulted in naturally appearing eyebrows with a relatively high survival rate. Graft survival rates were satisfactory even in patients who experienced complete hair loss after 2 years. The average graft survival rate among patients was 85 percent—higher than the average 78 percent survival rate in patients with traumatic scars. Jung et al.1 reported that the survival rate of grafts that did not completely cover scars was less than 60 percent. The grafts in the current study completely covered previous scars.

Several novel aspects of this procedure may improve graft survival rates and help obtain natural appearance. First, the indications for this method are strictly controlled and scar quality is well assessed. Before implementation of this procedure, careful evaluation of scar stability and vascularity were important to enhance graft survival rate. Subjective measurements of stability have shown moderate to high correlations with objective methods.25–29 Because successful hair transplantation requires reestablishment of the microcirculation, methods are needed to evaluate blood perfusion accurately in the scar area. Morphologic imaging is a precise and objective method that can evaluate the formation of new blood vessels and further determine blood flow perfusion. However, morphologic imaging equipment is expensive.30 Therefore, the current study used three feasible and objective methods. Second, selection of the optimal donor site is crucial in

Table 2. Demographic and Clinical Characteristics

| Characteristics       | Values (n = 167) |
|-----------------------|-----------------|
| Sex                   |                 |
| Male                  | 68              |
| Female                | 99              |
| Age, yrs, mean (range)| 26.43 (16–42)   |
| Eyebrow defect        |                 |
| Unilateral            | 62              |
| Bilateral             | 38              |
| Partial               | 67              |
| Cause                 |                 |
| Burn and scald        | 62              |
| Trauma                | 87              |
| Skin grafting         | 6               |
| Local flap            | 12              |

Table 3. Standardized Operating Procedure Measurement

| Measurements                  | Values (n = 167) |
|-------------------------------|-----------------|
| Survival rate, %, mean (range)| 85 (70–90)      |
| Satisfaction level           |                 |
| High satisfaction            | 159             |
| Satisfaction                 | 7               |
| Dissatisfaction              | 1               |
| High dissatisfaction         | 0               |
| Complications                |                 |
| Hematoma                     | 0               |
| Infection                    | 0               |
| Hemorrhage                   | 0               |
| Folliculitis                 | 0               |
| Pigmentation                 | 0               |
| Underwent encryption         | 8               |
making the reconstructed eyebrow appear more natural. Using trichoscopy, we chose an eyebrow shape closest in diameter to the original eyebrow. Third, hair direction and density should be adjusted when reconstructing eyebrows in several special situations. Moreover, single hair grafts are smaller and have lower metabolic requirements for survival than grafts containing two or three hairs, consistent with original eyebrows composed of a single hair per follicle unit. Finally, the method used to harvest hair follicles has been adjusted, from follicular unit transplantation to follicular unit extraction, resulting in no scarring in the donor area and fewer complications. This procedure has minimal surgical risk and a rapid effect, allowing patients to recover quickly, usually in 2 to 4 days. In addition, the follicular unit extraction technique has made the donor area unrestricted, allowing grafts to be taken from any site in the body, such as the head, beard, and legs.12,31,32

This procedure is not suitable for all eyebrows lost to scarring. These eyebrows may first require another treatment to create a good bed for implantation. [See Figure, Supplemental Digital Content 1, which shows a flowchart for reconstruction of individual scarred eyebrow based on scar quality, location, and type, http://links.lww.com/PRS/F388.] The scars resulting from eyebrow loss can be categorized as superficial, hypertrophic, atrophic, and keloid. Superficial scars are soft, with hair transplantation being as easy as in normal tissues. The tissue beds of hypertrophic and keloid scars are stiff and not on the same level as the surrounding skin, resulting in hair grafts at different depths and difficult insertion. Hypertrophic scars can be treated with corticosteroids to reduce inflammation and suppress hyperplasia, allowing hairs to be implanted when these scars soften. Keloid scars grow beyond the boundary of the previous wound and may require locally enlarged resection, resulting in a tissue bed insufficient for transplantation. None of the patients in the current study had hypertrophic or keloid scars on their eyebrows. Moreover, a study of 295 patients who underwent 414 thin scalp transplantations over 10 years found that none developed hypertrophic or keloid scars, indicating that pathologic scars rarely occur in the scalp or brow area. For atrophic scars, grafts should be inserted at an acute or near flat angle because the bed is very shallow. For hard scars, glucocorticoid or injection of autologous fat grafts can soften tissue. Autologous fat grafts consist primarily of adipose-derived stromal cells and stromal vascular fraction gel, which can minimize scar size and increase the quality and pliability of scars.35–42 Adipose stromal cells have been found to enhance skin neovascularization, allowing easy graft insertion and improving graft growth environments. Subcutaneous fat transplantation can also promote the regeneration of hair follicles in scarred areas, as good results were obtained when autologous fat grafts were used to treat atrophic scarring alopecia in eyebrows.41 Therefore, fat transplantation along with this standardized procedure is an alternative two-stage treatment for patients with stiff scars. Except for the abovementioned situations, scars that are relatively brittle or in the eyebrow arch may require more than two sessions to achieve a satisfactory density.

CONCLUSIONS

Because of the importance of eyebrows for facial aesthetics, it is necessary to restore cicatricial eyebrow loss. The method described in the current study is safe and practical for natural eyebrow reconstruction, with a high graft survival rate and ability to camouflage previous scars. Patients expressed high levels of postoperative satisfaction, even after a single session. This method is likely to be useful in the reconstruction of scarred eyebrows.

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PATIENT CONSENT

Patients provided written informed consent for the use of their images.

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