Improved hair restoration method for burns

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**A B S T R A C T**

Background: Extracted partial longitudinal follicular units can be used as complete follicular units to regenerate completely differentiated hair growth. The partial follicular units that remained in the dermis in the donor area can survive and produce hairs. This technique enables us to multiply hair follicles *in vivo*, while preserving the donor area and therefore is suitable in persons, who have a relative small donor area compared to the recipient area, as in scalp burns.

Objectives: With this study, we try to determine if partial longitudinal follicular unit transplantation (PL-FUT) can be used for facial and/or scalp burns.

Materials and methods: Four burn victims (age 22–39 years, mean 27.75 years) were treated in the face (eyebrows, and beard) and/or on the scalp with PL-FUT. The grafts were harvested with hollow wave-tipped needles with an inner diameter of 0.6 mm from the occipital area of the scalp. The suitable longitudinal partial follicular units were impregnated with a preservative medium, and implanted into the recipient area. Hair growth in the donor area as well as the recipient area was observed before treatment, and at intervals of 1 week, 3 months and 1 year after the treatment.

Results: After evaluation of the donor area, sometimes a few little white spots were visible, but almost all hair follicles in the donor site re-produce hairs after 2 years. All treated patients had satisfactory or very satisfactory cosmetic results in the treated area.

Conclusions: Longitudinal partial follicular unit transplantation (LP-FUT) may represent the first reliable patient-friendly method to generate two hair follicles from one hair follicle with consistent results and preservation of the donor area. Therefore, this method is very suitable for people with facial and/or scalp burns.

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The head, especially the scalp and face, plays a central role in the psychological as well as physical self-esteem of the individual. It transmits expressions and emotions, communicates feelings and allows for individual identity. Facial burns disrupt these anatomical and functional structures creating pain, deformity, swelling and contractures that may lead to lasting physical and psychological problems [1].

Although the extent of psychological trauma depends on the gender of the patient, age at the time of burn, stage of adolescence, intelligence and on the position and degree of burn, in general, facial- and scalp burns a significantly negative effect on the self-esteem of the patient [2].

Therefore, reconstructive treatments for facial- as well as the scalp burns are very important for the physical as well as physiological well-being of the patient.

Almost one-third of all burns are facial burns [3]. Because hair on the face and scalp facial hair and scalp play a major role in cosmesis and expression of the individual, especially, hair restoration of the face (eyebrows, beard, etc.) and scalp may be beneficial for the self-esteem of the patient. Restora-
tion of eyebrows, beard and scalp is possible with hair transplantation techniques. In addition to hair transplantation, scalp reductions are also commonly used in the treatment of facial and scalp burns [4].

The ideal hair transplantation in burns should fulfil the following objectives:

1. excellent cosmetic outcome;
2. total hair re-growth of the transplanted hair follicles;
3. complete preservation and, therefore, endless source of donor hair follicles;
4. no scarring;
5. safe and comfortable procedure;
6. short treatment duration;
7. no recovery time; and
8. inexpensive.

Of all available hair transplantation techniques, there is no technique which fulfils all the mentioned criteria. There are different techniques of hair transplantation, with their advantages and disadvantages. The most common and known hair transplantation method is the so-called ‘strip’ method [5]. A strip of skin containing hair follicles is removed, cut into grafts and implanted in the recipient area. In the past years, new methods have developed of which the most promising is the follicle unit extraction (FUE) method [6]. With this method, whole follicle units are extracted one by one and implanted one by one back into the recipient area. Although the FUE method is more patient friendly and leaves only tiny scars compared with the strip method, which leaves visible linear scars at the donor area, the major disadvantage of both methods is that the extracted hair follicles are removed and the source of potential grafts will be consumed in time. The cosmetic result depends not only on the grafts type (single-hair grafts or follicular units), the survival rate of the transplantation and the skill of the surgeon, but also on the number of grafts one can transplant. Besides hair transplantation, scalp reduction is also commonly used in the treatment of facial and scalp burns [4].

In burn victims, due to depletion of the donor area, especially when the donor area is also burned, hair transplantations with the described methods will always limited by the availability of donor hair follicles, because no re-growth will occur in the donor area, and therefore limits the possibilities of hair transplantations in burn victims.

The only way to preserve a significant part of the donor hair follicles could be partial FUE. This idea is not unrealistic and is supported by different experiments [7,8]. Kim and Choi [7] found that, in humans, the proximal part of the hair follicle cannot regenerate into a differentiated hair follicle, but the distal part of the follicle can, eventually resulting in a fully developed hair follicle [9]. Reynolds et al. found that, although the dermal papillae of humans cannot induce new hair growth, the sheath of the lower part of the hair follicle can [8]. These apparently contradictory results indicate that both the proximal and distal areas of the hair follicle should contain follicular stem cells that can induce hair growth [10].

Partial follicular units can be obtained as: transversal [7] and longitudinal [11].

We report here about the possibility to use partial longitudinal follicular unit transplantation (PL-FUT) for burn patients. With this technique, follicular stem cells remain at the donor site as well in the extracted partial follicle. In this case, two hair follicles can be generated from one as long as only a part of the follicle is dissected from the original source.

It is also important to realise that, practically, harvesting partial follicular units with the preservation of the donor follicular units can only be obtained in large quantities if they are from the longitudinal type.

PL-FUT represents the first reliable patient-friendly method to generate two hair follicles from one hair follicle with consistent results and preserve the donor area. This technique could, therefore, be suitable for people with very limited donor area, for example, burn victims. In this article, we reveal the possibilities of the PL-FUT for facial and scalp burns.

<table>
<thead>
<tr>
<th>Case</th>
<th>Initials</th>
<th>Date of birth</th>
<th>Treatment</th>
<th>Treatment date</th>
<th>Location</th>
<th>Number of grafts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>KZ</td>
<td>2-8-1986 (23 years)</td>
<td>1</td>
<td>29/30-06-2005</td>
<td>Eyebrows</td>
<td>595 + 502 grafts</td>
</tr>
<tr>
<td>2</td>
<td>MS</td>
<td>29-4-1986 (24 years)</td>
<td>1</td>
<td>08/09-03-2006</td>
<td>Scalp</td>
<td>572 + 675 grafts</td>
</tr>
<tr>
<td>3</td>
<td>HW</td>
<td>10-12-1969 (40 years)</td>
<td>1</td>
<td>04-04-2007</td>
<td>Scalp</td>
<td>852 grafts</td>
</tr>
<tr>
<td>4</td>
<td>BT</td>
<td>22-7-1970 (29 years)</td>
<td>1</td>
<td>15-04-2008</td>
<td>Scalp</td>
<td>662 grafts</td>
</tr>
<tr>
<td>5</td>
<td>BT</td>
<td>22-7-1970 (29 years)</td>
<td>1</td>
<td>24-09-2006</td>
<td>Eyebrows</td>
<td>300 grafts</td>
</tr>
<tr>
<td>6</td>
<td>BT</td>
<td>22-7-1970 (29 years)</td>
<td>1</td>
<td>15-08-2007</td>
<td>Scalp</td>
<td>300 grafts</td>
</tr>
<tr>
<td>7</td>
<td>BT</td>
<td>22-7-1970 (29 years)</td>
<td>1</td>
<td>23-10-2008</td>
<td>Beard</td>
<td>600 grafts</td>
</tr>
</tbody>
</table>

Fig. 1 – Close-up of the triple-waved tipped extraction needle.
1. Materials and methods

1.1. Patients

Four burn victims (age between 22 and 39 years), who consulted Hair Science Institute with facial and scalp burns, have been treated in the face as well as on the scalp with PL-FUT (Table 1). In this article, we will discuss these patients.

1.2. PL-FUT

1.2.1. Preparation of the donor site

On the occipital side of the scalp, an area of 15 × 5 cm was shaved, disinfected with chlorhexidine 2% lotion and anaesthetised with lidocaine 2% with adrenaline (AstraZeneca).

1.2.2. Extraction of the partial longitudinal follicular units (grafts)

The grafts were harvested with hollow triple-waved tipped, partial blunt needles with an inner diameter of 0.6 mm (Fig. 1) (Hair Science Institute®, Amsterdam, the Netherlands) under 2 × magnification. This needle uses the coarse, dead hairs as a guide and enables us to extract a partially longitudinal follicular unit, even when the follicular unit is not in a perfect triangular configuration.

Fig. 2(a) shows a follicular unit, containing the visible hairs (brown), hair follicle (dark pink) and connective tissue (white). The needle is placed around the visible hairs and then twisted in the same direction until the grafts are detached from the dermis (Fig. 2(a) and (b)). The grafts are extracted with microsurgical forceps (Fig. 2(c)). The aim of the extraction is to remove only a part of the follicle unit, containing follicle and connective tissue from several hair follicles, and leave sufficient follicle unit tissue behind to regenerate hairs (Fig. 2(d) and (e)). After the extraction, Fucidin Cream® (Leo Pharma, Breda, the Netherlands) is applied on the donor area.

Partial longitudinal follicular units (Fig. 3(a1) and (a2) (Haematoxylin and Eosin (HE) stained transversal sectioned partial longitudinal follicular unit (20×))) are different from complete follicular units (Fig. 3(b1) and (b2) (HE stained transversal sectioned complete follicular unit (10×)), because partial longitudinal follicular units leave a considerable part of the original follicular unit behind at the donor site. They can be distinguished from complete follicular units because partial longitudinal follicular units show terminal hairs at the border and do not contain surrounding tissue and complete follicular units contain complete hair follicles with surrounding tissue.

After extraction, the partial longitudinal follicular units were stored in the preservative medium, which is composed of the following ingredients: sodium chloride, potassium chloride, magnesium sulphate, sodium phosphate, calcium chloride, glucose, sodium bicarbonate, sodium lactate, sodium pyruvate, human serum albumin, insulin, bis(maltolato)oxovanadium (BMOV) and α-tocopherol (vitamin E) (Hair
Science Institute, Amsterdam, the Netherlands) for 2 h until implantation.

1.2.3. Preparation of the recipient area
The recipient area was disinfected with chlorhexidine 2% lotion and anaesthetised with Prilocainhydrochloride 30 mg ml$^{-1}$ (3%) en felypressine 0.54 μg ml$^{-1}$ (Citanest) (AstraZeneca). Miniscule holes were made with a hollow needle with an inner diameter of 0.6 mm needle (Hair Science Institute, Amsterdam, the Netherlands) and skin was removed or the grafts were implanted directly after making the holes with a 21G hypodermal.

1.2.4. Implantation of the grafts
After the preparation of the recipient area, the grafts were implanted with microsurgical forceps.

1.2.5. Follow-up
At intervals of 1 week, and 3 and 12 months after the extraction, the donor area as well as the recipient area was photographed.

2. Results

2.1. The donor area
Fig. 4 shows the donor area of a patient before (Fig. 4(a)), and 3 years later after four treatments and 3858 grafts extracted (Fig. 4(b)). After evaluation of the donor area, there are a few little white spots visible, but almost all hair follicles in the donor site reproduce hairs after 3 years.

Fig. 4 – Pictures of the donor area. (a) Picture of the donor area of a patient before harvesting the grafts. (b) Picture of the donor area of a patient after three years (4 treatments, 3858 grafts extracted).

![Fig. 4](image_url)

Fig. 5 – Case 1: KZ after 4 treatments, 3858 grafts. (a) Frontal aspect, before treatment. (b) Frontal aspect, after four years. (c) Top view, before treatment. (d) Top view, after four years.

Fig. 5 – Case 1: KZ after 4 treatments, 3858 grafts. (a) Frontal aspect, before treatment. (b) Frontal aspect, after four years. (c) Top view, before treatment. (d) Top view, after four years.
2.2. Re-growth of the hairs in the recipient area

Fig. 5 shows the first case (KZ, 23 years), who had, in total, 3858 grafts spread over four consecutive treatments on the scalp and eyebrows during a period of 3 years. The eyebrows were fully restored and the scalp is almost completely covered. She was very satisfied with the result.

Fig. 6 shows the second case (MS, 24 years), who had in total 300 grafts in one session to restore the eyebrows. The eyebrows have been fully restored. Because the eyebrows are very important for the expression of the face, she was very satisfied with the result.

Fig. 7 shows the third case (HW, 40 years), who had, in total, 300 grafts in one session to restore the temple. The temple has been fully restored and she was very satisfied with the result.

Fig. 8 shows the fourth case (BT, 29 years), who had, in total, 600 grafts in one session to restore the beard area. Consecutive treatments will be necessary to increase the density in the beard. However, as the first session already camouflaged the most visible scars in the area, he was already satisfied after the first treatment.

Satisfactory cosmetic results are defined as a natural result with a density which covers the scalp. Because these objectives are achieved, all treated patients were satisfied or very satisfied with the results.

3. Discussion

Although hair transplantation is the best option for facial burn scars, it is really a challenge for the surgeon, because scar tissue behaves differently from normal skin.

In contrast to traditional hair transplantation techniques, which require a strip removal with a depth of 1–1.5 cm to obtain the hair follicles, we showed that successful transplantation in burn scars is feasible using longitudinal partial follicular units with a diameter of 0.5–0.6 mm, and 5–6 mm in length. Due to minimal skin and tissue removal, in the above-mentioned cases, there was minimal to no scarring, pain or other post-surgical trauma such as nerve and vascular damage. In contrast with the traditional hair-transplantation techniques, there is no linear scar, and, therefore, it is impossible that the linear scar will ‘stretch out’ over time. Further, no stitches or bandages are required.

Potential risks could be density loss of the donor area when the grafts are extracted to close to each other, failure of growth of the implanted PL-FUs due to bad vascularisation as well as necroses when the grafts are implanted too close to each other. However, none of these occurred in the above-mentioned cases.
This study shows that partial longitudinal follicular units containing viable follicular stem cells with connective tissue can, even with the complicated tissue characteristics of the recipient site, be used for restoration of the facial hair as well as the scalp in burn victims. Because the partial follicular units, which remain in the dermis in the donor area can survive and re-produce hairs, these follicular units in the donor area can be used again in consecutive treatments. However, more experience with the PL-FUT in burn victims is necessary to evaluate the limitations and further possibilities of this technique.

The main difference between the technique of PL-FUT compared with the other hair-transplantation techniques is the preservation of the donor hair follicles without scarring. As, often in burn victims, this donor area is limited, this aspect is very important. Further, this is especially true for this group of patients.

PL-FUT is a very labour-intensive procedure and to transplant sufficient grafts takes a full day. However, this technique may represent the first reliable patient-friendly method to generate two hair follicles from one hair follicle.

Fig. 7 – Case 3: HW after 1 treatment, 300 grafts. (a) Left temporal scalp, before treatment. (b) Left temporal scalp, directly after treatment. (c) Left temporal scalp, 1 week after treatment. (d) Left temporal scalp, 8 months after treatment.

Fig. 8 – Case 4: BT after 1 treatment, 600 grafts. (a) Beard, before treatment. (b) Beard, directly after treatment. (c) Beard, 1 year after treatment.
with consistent results and preservation of the donor area. Therefore, this method is very suitable for people with very limited donor area, the most extreme example of this being burn victims. All of the presented patients in this article got reimbursement from their health insurance companies.

In general, we prefer the improved hair transplantation method PL-FUT above all other surgical possibilities for hair restoration such as traditional hair transplantation techniques (strip-method or FUE).

REFERENCES


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