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ORIGINAL ARTICLE

Clinical application of intense pulsed light depilation technology in total auricular reconstruction

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Abstract Although ear reconstruction technology has been highly developed in recent years, hair growth on the reconstructed ear has plagued both surgeons and patients. In this paper, the authors introduce a clinical application of intense pulsed light depilation in total auricular reconstruction. From August 2012 to August 2013, 27 patients (28 ears) suffering from congenital microtia were treated by intense pulsed light depilation (650–950-nm filter, initial fluence of 14–16 J/cm^2 and gradually increased, pulse width of 30–50 ms, spot size of 20 × 30 mm^2, intervals of 6–8 weeks, a total of four sessions) either before or after auricular reconstruction. According to the treatment situation at diagnosis, the patients were divided into two groups: the preoperative group and the postoperative group. There were no differences between the two groups in terms of age or initial fluence for hair removal; however, there were less treatments in the former than in the latter group (preoperative group 4.1 ± 0.3, postoperative group 4.7 ± 0.7, $F = 9.10$, $P = 0.006$), and the maximum fluence used for hair removal was lower in the former than in the latter group (preoperative group 18–20 J/cm^2, postoperative group 19–22 J/cm^2, $F = 22.31$, $P < 0.001$). After follow-up for ≥4–6 months, the effective rate was 100% in the preoperative group, and the effective rate was 80% in the postoperative group. Intense pulsed light depilation technology is a reasonable complementary approach to total auricular reconstruction. And preoperative depilation is recommended over postoperative depilation. The non-invasive modern photonic technology can resolve the problem of postoperative residual hair on the reconstructed auricle, improving auricular shape and increasing patient satisfaction. In addition, an adequately set preoperative hair removal area can provide surface skin that is most similar to normal auricle skin for auricular reconstruction.

Keywords Intense pulsed light · Hair removal · Congenital microtia · Auricular reconstruction

Introduction

Total auricular reconstruction has long been a challenge for orthopedists and otologists. Successfully reconstructing the external ear not only requires a precise cartilage framework to outline its special contours but also must be covered with normal skin. To resolve the problem of skin covering, skin grafting or using a postauricular tissue expander [1, 2] to expand the skin flap is commonly used; however, a skin graft can only resolve the problem of quantity while introducing an issue of skin color difference. In particular, the front part of the auricle often shows an uneven spotty color, which is unacceptable to the patients. In addition, the majority of patients have a low retroauricular hairline. Even with the use of a postauricular tissue expander, adequate skin cannot be provided within a few months to cover the total auricle, especially the skin of supra-auricular tissue [3].

In the Department of Otolaryngology at our hospital, the modified Nagata technique commonly requires a portion of the postauricular or supra-auricular scalp tissue to bury an auricular framework during the first stage of the operation.

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Both patients and surgeons are not pleased with the cosmetic appearance of the auricle with hairs present. In 2012, the intense pulsed light (IPL) technique was used to remove unwanted hair from these regions for adjunctive therapy on 27 patients before or during total auricular reconstruction. The difference of treatment results between the preoperative group and the postoperative group was discussed in the study. It will help to improve the treatment process of total auricular reconstruction.

Materials and methods

From August 2012 to August 2013, 27 patients suffering from congenital microtia visited our department (Department of Plastic Surgery) for hair removal either before or after auricular reconstruction. The age of the patients ranged 6 to 26 years, with an average age of 12.85 years. The patients in the study had Fitzpatrick skin types III or IV. Based on the treatment situation at diagnosis, the patients were divided into the following two groups: (1) the preoperative group (17 patients, 18 involved ears, 15 males, 2 females) were those who needed to undergo total auricular reconstruction but had a lower periotic hairline; these patients were asked not to consider the surgery before one course of hair removal treatment was completed; (2) the postoperative group (10 patients, 10 involved ears, 8 males, 2 females) were those patients who had undergone stages I–II auricular reconstruction using the Nagata technique, with obvious hair growth in a partial area of the reconstructed auricle (Fig. 1).

For eligible patients, the involved ear was compared with the normal ear. CT (SOMATOM Definition Edge, Siemens, Germany) data were combined to build a model to further determine the location and size of the reconstructed ear. The contour of the auricle was marked with a red line, then expanded by 1.5–2.0 cm and remarked on the supra-auricular and postauricular parts. The area within the expanded contour was defined as the hair removal treatment area (Fig. 2).

Before hair removal, the treatment area was trimmed with scissors (YYJ-PT160, Cofoe®, Hunan, China) and shaved using a disposable scraper blade (74-C, Flying Eagle®, Shanghai, China). Anesthesia was unnecessary.

All patients were treated using the Harmony™ Multi-Application Laser System (Alma Lasers, Ltd., Caesarea, Israel, 650–950-nm filter, with spot size of 20 × 30 mm^2). Patients wore protective goggles (YL800W Safety Eye Guard, Alma Lasers, Ltd., Caesarea, Israel) or had their eyes covered with wet gauze (7.5 × 7.5 cm^2-8P, Winner®, Hubei, China). Young children were accompanied by a family member (also wearing protective goggles). The patients were set in a supine position; the head was turned to the healthy side to expose the involved ear. A cold-set gel was applied to the skin surface within the treatment area, and normal skin as well as the hairy site were covered with a white light-shielding plate. Appropriate parameters were chosen in accordance with Fitzpatrick [4] skin type and character of hairs. Fitzpatrick skin type of Asian was type III or IV. Initial fluence was often at 14–16 J/cm^2 and gradually increased. The recommended initial pulse width was 50 ms, which could be changed to 30–40 ms since the second treatment. Because the skin was covered with too many hairs, it was hard to confirm the

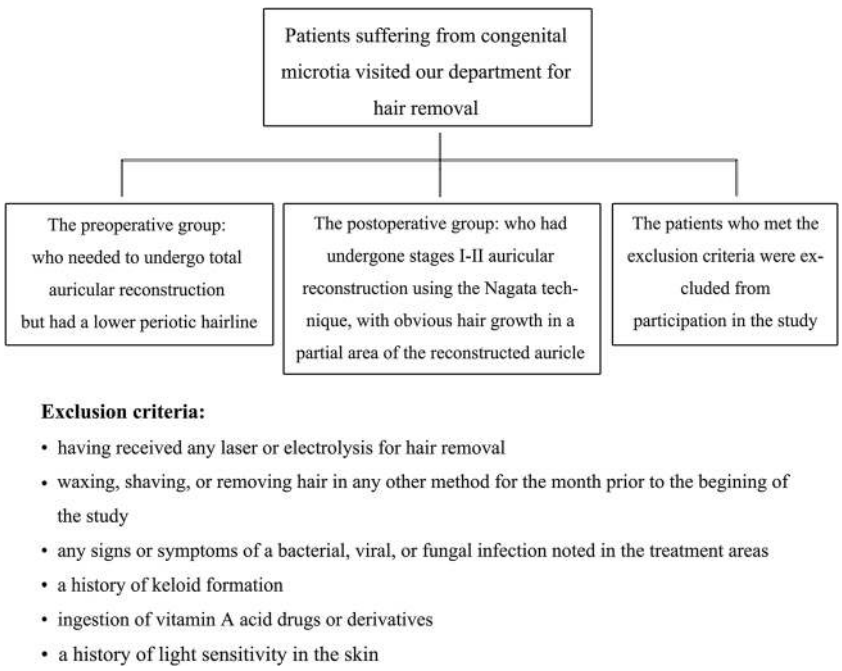

Fig. 1 The inclusion and exclusion of participants for various selected surgical groups

Fig. 2 The area within the expanded contour was defined as the hair removal treatment area

Fitzpatrick skin type in the first treatment. Longer initial pulse width was chosen to reduce complications, such as empyrosis. Since the second treatment, with hairs decreased, appropriate parameters could be chosen in accordance with Fitzpatrick skin type and character of hairs. In general, the end point was when the patient felt pain, the skin became reddish, or the perifollicular edema and erythema were evident; residual hair roots then shed over the next few days. The treatment area was scanned once according to the size of the light spots. There had to be a 20% area of overlap between two spots so as to cover the edge, but normal skin was protected from repeated irradiation.

In the postoperative group, because the auricular framework was already reconstructed, the treatment area had irregular morphologies and the hairy area was generally located at the exterior auricular rim or postauricular hidden area. Thus, the direction of the Harmony™ hand tool (Alma Lasers, Ltd., Caesarea, Israel) was adjusted several times during irradiation to make contact with the treatment area as directly as possible. Meanwhile, the normal areas were protected from repeated irradiation. The deep area of auriculocephalic sulcus and the rear area of the auricle were difficult to access with the device handpiece; therefore, a longer pulse duration and higher energy were utilized in conjunction with extra cold-set gel (Medical Ultrasound Gel, SF-cores®, Henan, China) to fill the auriculocephalic sulcus, aiding in light conduction and accurate photothermolysis of the hair follicles.

After the treatment, skin changes were examined and a cold compress was applied to the irradiated skin. The patients were asked to avoid getting the area wet after treatment for 1 day and to use proper sun protection during the course of the hair removal procedures. Return visits were required once hair growth in the treatment area was noted, generally at intervals of 6–8 weeks for a total of four sessions. During each treatment, the skin area was photographed (Digital Still Camera, DSC-F707, Sony®, Japan) and the hair conditions as well as treatment parameters were recorded.

Data were compared using a continuous data statistical description and analysis of variance with SPSS (Chicago, ILL, USA). The continuous variables were presented as mean ± SD (standard deviation) when they were distributed normally. Analysis of variance (ANOVA) was used to compare the differences between preoperative and postoperative groups. A P value <0.05 was considered statistically significant. With the sample size in this study, and the mean of the times of treatment, the estimated power of the comparison was 83–95%.

Results

After hair removal treatment, the patients were followed from 4 to 6 months for comparative analysis of hair removal treatment parameters and results between the two groups. The curative effect of hair removal was ranked into four levels: cured, markedly effective, effective, and ineffective. Cured: hair density per square centimeter decreased by ≥90% and hairs mostly or completely disappeared; the patient is very satisfied. Markedly effective: hair density per square centimeter decreased by 60–89% and new hairs become thinner, softer, and lighter; the patient is satisfied. Effective: hair density per square centimeter decreased by 30–59%, and new hairs become thinner, softer, and pale; the patient is generally satisfied. Ineffective: hair density per square centimeter decreased by ≤29% and thick hairs continue to grow; the patient is unsatisfied.

All the patients had accepted the treatment and index assessment. Patients in the preoperative group ranged in age from 6 to 26 years, with an average age of 12.4 ± 6.1 years when hair removal began. The patients, on average, underwent 4.1 ± 0.3 treatments for hair removal. The initial fluence ranged from 14.0 to 17.0 J/cm^2, with a mean value of 16.0 ± 0.7 J/cm^2. The maximum fluence ranged from 18.0 to 20.0 J/cm^2, with a mean value of 19.1 ± 0.5 J/cm^2 (Table 1).

Patients in the postoperative group ranged in age from 8 to 22 years, with an average age of 13.7 ± 4.1 years. The patients, on average, received 4.7 ± 0.7 treatments for hair removal. The initial fluence ranged from 15.0 to 17.0 J/cm^2, with a mean value of 16.1 ± 0.6 J/cm^2. The maximum fluence ranged from 19.0 to 22.0 J/cm^2, with a mean value of 20.3 ± 0.8 J/cm^2 (Table 1).

There were no significant differences between patients in the preoperative group and those in the postoperative group in terms of age or initial fluence for hair removal; however, there were less treatments in the former than in the latter group (F = 9.10, P = 0.006), and the maximum fluence used for hair

Table 1 The age, number of treatments, initial fluence, and maximum fluence of the preoperative and postoperative groups

	Age (years)	No. of treatments	Initial fluence (J/cm^2)	The maximum fluence (J/cm^2)
Preoperative	6~26	4.1 ± 0.3	14~17	18~20
Postoperative	8~22	4.7 ± 0.7	15~17	19~22

removal was lower in the former than in the latter group ($F = 22.31$, $P < 0.001$).

Four to six months after completion of the four treatment sessions, 13 patients reached the cured level of effectiveness, two reached the markedly effective level, and two reached the effective level in the preoperative group, accounting for an effective rate of 100%. In the postoperative group, four patients reached the cured level of effectiveness, three reached the markedly effective level, one reached the effective level, and two reached the ineffective level, accounting for an effective rate of 80%. Subjects who did not achieve "Cured" or "Markedly effective" hair removal status after four treatment sessions were allowed additional treatments. After two to three additional treatments with higher energy, all effective and ineffective cases met the criteria for the markedly effective level. There were two patients who experienced slight blistering in the postoperative group; however, no special treatment was necessary. After escharosis and healing, no complications, such as a change in pigmentation, occurred (Table 2, Figs. 3, 4, and 5).

Discussion

A variety of conventional methods are available for hair removal, such as shaving, plucking, waxing, and chemicals, which provide temporary effects and often involve adverse reactions. With the introduction of laser technology, Ono [5] was the first to use lasers for resolving the problem of hair growth on the reconstructed ear. Similar studies have also been reported in China [3, 6].

IPL depilation uses the same principle as laser hair removal. IPL is a broad-spectrum light with a range within 645 and 1200 nm, which can be absorbed by melanin [7–9]. Compared with a single wavelength laser, broad-spectrum light can not only damage hair growth-related structures but also improve the quality of the target skin.

In IPL mode, one pulse of energy is divided into two to three subpulses for the treatment. The thermal relaxation time of the epidermis is 3–10 ms, and that of the hair shafts and hair follicles is 40–100 ms [10]. The pulse interval between subpulses does not increase the temperature in the target tissue, allowing the epidermis to have a specific cooling time after the pulse. This multipulse mode can better protect the epidermis than the single-pulse mode. The former reduces pain and protects the surface skin, resulting in a safer and more comfortable treatment for patients [11, 12].

In particular, for those with congenital microtia who were diagnosed between the ages of 6 and 18 years, the pain from laser hair removal might not be tolerated. In our department, the Harmony™ (Alma Lasers, Ltd., Caesarea, Israel) is a working platform that supports many technologies, including pulsed light and laser technology. The hair removal handpiece is one of various modules with a high-powered targeted handpiece, working in the red wavelength range (650–950 nm), and with adjustable parameters for effective hair removal.

The hand tool produces a spot size 2 × 3 cm^2 and comes with a contact-type condensing device, which can rapidly reduce the surface temperature of the tissue. In addition, because of the combined skin-tendering effect of pulsed lights, after a course of light-heat stimulation, hair follicles will shrink in the originally hairy skin area, and the target skin will become smooth with significantly improved elasticity and texture [13, 14], thereby providing the necessary material for the next step in auricular reconstruction.

Hair growth is cyclical, and only hairs in the anagen are the most active. In this phase, hair follicles contain the most melanin, making laser or pulsed light therapy most effective during this time [15]. By comparison, hair follicles in the degradation or telogen phase are insensitive, and the patient needs to wait until the next growth cycle for treatment. The normal telogen phase of the scalp lasts 6–12 weeks, which is often extended by the first treatment. Thus, it is necessary and effective for the interval between treatments to be 6–8 weeks; the entire course of hair removal treatment is 7–8 months.

Patients with congenital microtia commonly have a middle ear deformity. Surgical treatment for these patients is generally

Table 2 After follow-up for ≥4–6 months, the number of different cured level in the preoperative and postoperative groups

	Cure	Markedly effective	Effective	Ineffective	An effective rate (%)
Preoperative	13	2	2	0	100
Postoperative	4	3	1	2	80

Fig. 3 This is one patient of the preoperative group. *Top left*, before depilation and surgery. *Top right*, after depilation, before surgery. *Bottom left*, 1 month after surgery. *Bottom right*, 6 months after surgery

Fig. 4 This is another patient of the preoperative group. *Left,* before depilation and surgery. *Middle*, after depilation, before surgery. *Right*, 3 months after surgery

Fig. 5 This is one patient of the postoperative group. *Left*, after surgery, before depilation. *Right*, after depilation

divided into stage III–V repair, performed over several years. Early completion of auricular reconstruction can not only improve the deformity but also contribute to the patient's psychological and social development; therefore, it is particularly important in these cases to reasonably and orderly arrange the timing of the surgery. Most of these types of surgeries must be performed with the cooperation of orthopedists and otologists. When performing total auricular reconstruction, the orthopedist should ensure that the otologist has completed the required audiological and radiological assessments. When doing the audio-surgery, the otologist must fully assess the deformity of the auricle and discuss the surgery plan with the orthopedist [16].

Most otologists consider that any age >6 years is suitable for hearing reconstruction. Taking into account the impact to other aspects such as psychology and anatomical development, the ages from 5 to 6 years are also optimal for auricular reconstruction [17]; therefore, early surgical planning and completion of hair removal for expanding the surgical area are beneficial to the orderly completion of the entire treatment plan.

According to the results presented in this study, hair removal through a simple operation before surgery resulted in smooth skin in the treatment area. The dose of IPL energy was gradually increased with only rare complications, such as erythema and blisters. One treatment course of four laser sessions 6–8 weeks apart was 100% effective for hair removal. By comparison, when hair removal was performed after the auricular framework was implanted, the treatment area could not be uniformly irradiated with pulsed light because of the complex structure and uneven surface of the auricle. Repeated irradiation of the overlapping area might cause thermal damage and formation of the auriculocephalic sulcus; consequently, part of the skin with hairs hidden behind the ear was difficult to directly irradiate, negatively affecting complete hair removal. Although these cases were cured after an increased number of treatments with higher fluence, two patients had blisters and scabs on their skin. In a word, preoperative depilation with IPL was more effective, safe, and economical.

In this study, we found that hair removal from the skin after the auricular framework was implanted had no negative impact on the cartilage framework underneath the skin. During the 4–6-month postoperative follow-up period, there were no complications, such as cartilage deformation or cartilage absorption.

Conclusions

Intense pulsed light depilation technology is a reasonable complementary approach to total auricular reconstruction. The noninvasive modern photonic technology can resolve the problem of postoperative residual hair on the auricle, improving auricular shape and increasing the patient's satisfaction. In addition, an adequately set preoperative hair removal area can provide surface skin that is most similar to the normal auricle for auricular reconstruction. And preoperative depilation is recommended over postoperative depilation. The operation is simple, which is more conducive to completion of the entire treatment plan. We believe that proper and reasonable use of intense pulsed light depilation technology will provide new avenues by which auricular reconstruction can be more successful.

Compliance with ethical standards

Ethical approval The study was approved by the Ethical Committee of Eye and ENT Hospital of Fudan University (number 2015001-3). All procedures performed in the present study were in accordance with the Declaration of Helsinki.

Informed consent All participants or their parents were given information about the study, and written informed consent was obtained from all participants or their parents.

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. Park C (2000) Subfascial expansion and expanded two-flap method for microtia reconstruction. Plast Reconstr Surg 106:1473–1487
2. Zhang HX, Jiang HY, Pan B (2006) Ear reconstruction using soft tissue expander in the treatment of congenital microtia. Zhonghua Zheng Xing Wai Ke Za Zhi 22:286–289
3. Liu JF, Sun JM, Zhang YM (2007) Clinical research of intense pulsed light depilation combined with bigger skin expander in auricular reconstruction. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 21:921–924
4. Fitzpatrick TB (1988) The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol 124:869–871
5. Ono I (2002) Therapeutic effect of using a long-pulsed alexandrite laser system with a cooling device for epilation in reconstructive surgery of auricular malformations. Ann Plast Surg 48:115–123
6. Li T, Ma Y (2012) Long-pulsed Nd:YAG 1064nm laser treatment of depilation in auricular reconstruction. Zhongguo Mei Rong Yi Xue 21:100
7. Ross EV, Ladin Z, Kreindel M, Dierickx C (1999) Theoretical considerations in laser hair removal. Dermatol Clin 17:333–355 **viii**
8. Liew SH, Grobbelaar AO, Gault D, Green C, Linge C (1999) Ruby laser-assisted hair removal: a preliminary report of the correlation between efficacy of treatment and melanin content of hair and the growth phases of hair at a specific site. Ann Plast Surg 42:255–258
9. Slominski A, Paus R, Plonka P, Chakraborty A, Maurer M et al (1994) Melanogenesis during the anagen-catagen-telogen transformation of the murine hair cycle. J Invest Dermatol 102:862–869
10. Lask G, Eckhouse S, Slatkine M, Waldman A, Kreindel M et al (1999) The role of laser and intense light sources in photo-epilation: a comparative evaluation. J Cutan Laser Ther 1:3–13
11. Sadick NS, Weiss RA, Shea CR, Nagel H, Nicholson J et al (2000) Long-term photoepilation using a broad-spectrum intense pulsed light source. Arch Dermatol 136:1336–1340
12. Huo MH, Chen GZ, Yao LY (2005) Hair removal with intense pulsed light. Zhonghua Zheng Xing Wai Ke Za Zhi 21:288–290
13. Negishi K, Wakamatsu S, Kushikata N, Tezuka Y, Kotani Y et al (2002) Full-face photorejuvenation of photodamaged skin by intense pulsed light with integrated contact cooling: initial experiences in Asian patients. Lasers Surg Med 30:298–305
14. Bitter PH (2000) Noninvasive rejuvenation of photodamaged skin using serial, full-face intense pulsed light treatments. Dermatol Surg 26:835–842 **discussion 843**
15. Mandt N, Troilius A, Drosner M (2005) Epilation today: physiology of the hair follicle and clinical photo-epilation. J Investig Dermatol Symp Proc 10:271–274
16. Kelley PE, Scholes MA (2007) Microtia and congenital aural atresia. Otolaryngol Clin N Am 40:61–80 **vi**
17. Zhang TY (2012) Progress of staged combined surgery in congenital malformation of external and middle ear. Zhongguo Yi Xue Wen Zhai: Er Bi Yan Hou Ke Xue 27:8–10