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A nasolabial fold reset technique for enhancing midface lifts in facial reanimation: Three-dimensional volumetric analysis

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ABSTRACT

Despite successfully gaining excursion after free muscle transfer for facial palsy, soft tissue asymmetry, especially around the nasolabial fold (NLF) and medial cheek, is a troublesome problem in elderly patients. An NLF reset technique that enhances midface lifts has been introduced to overcome this problem.

Our study included 43 consecutive patients who underwent facial reanimation surgery with free functional muscle transfer between March 2015 and July 2017. Of these, 20 patients underwent conventional procedures and 23 underwent our NLF reset technique. Postoperative oral commissure excursion and symmetry at rest and while smiling were quantified using FACEgram (Facial Assessment by Computer Evaluation) software. To detect soft-tissue changes after surgery, three-dimensional analysis was performed using Morpheus®, a 3D, LED-based, white-structured-light scanner.

The NLF group had a significantly larger postoperative mean excursion at rest (control 25.32 ± 2.80 mm vs NLF 27.42 ± 3.60 mm; $p = 0.047$). The mean horizontal length ratios (affected-to-healthy) revealed better symmetry in the NLF group (resting 1.05 ± 0.22, smiling 0.97 ± 0.19; $p = 0.201$). The three-dimensional midface volume difference was significantly lower in the NLF group. The NLF reset technique produced improved surgical outcomes.

An incision made along a mirrored NLF can influence midface lifting in patients with facial palsy, with the soft tissue concentrated in the lower face mobilized superomedially.

1. Introduction

Functional muscle transfer is considered the procedure of choice for facial reanimation surgery (Bhama et al., 2014). Gracilis muscle transfer has achieved successful flap survival with reasonable improvement in smile excursion. Excellent results, such as 87% symmetry and high spontaneity recovery scores, have been attained through this microsurgical approach (Bianchi et al., 2010; Hontanilla et al., 2016). Numerous studies have focused on searching for more powerful neural sources to achieve restoration of facial expression.

Despite successfully gaining smile excursion after free muscle transfer, soft tissue issues persist in patients with facial palsy. Soft tissue asymmetry, especially around the nasolabial fold (NLF) and medial cheek area, is a troublesome concern in elderly patients. The characteristics of the affected side in patients with facial palsy include brow descent, facial soft tissue descent, absence of the NLF, and deep jowl formation, which are features attributed to the appearance of aging. To control soft tissue drooping, soft tissue management on the palsy side is necessary in addition to muscle inset manipulation. Moreover, an understanding of soft tissue characteristics is required.

With respect to rejuvenative aspects, facial reanimation surgery trials have been performed in which the facelift procedure is combined with free muscle transfer (Biglioli et al., 2011). However, we suggest the concept of 'dynamic rejuvenation', which is a more advanced process that involves free functional muscle transfer with rejuvenation.

Initially, we performed NLF reset in middle-aged patients with a complaint of midcheek drooping after a successful facial reanimation surgery. To improve the midcheek lift procedure, we performed free functional muscle transfer and the NLF reset technique

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simultaneously. Until now, no cases of this combination, including the midface lift procedure, have been reported.

In the one-stage procedure, the NLF incisional approach was performed for the transferred muscle inset. The human NLF is believed to be the product of a complex mechanism consisting of skin redundancy in the cheek, dermal attachment of the facial muscle, and conjugation of the modiolus. This slender, deep skin fold has the remarkable ability to support large quantities of soft tissue superolaterally. Owing to the complexity of the expression of a smile, midcheek abundancy interferes with spontaneous natural smile initiation, and the NLF plays a crucial role in this process.

In this study, we introduce an NLF reset technique for enhancing midface lifts, and demonstrate its effectiveness using three-dimensional (3D) volumetric analysis.

2. Materials and methods

2.1. Patients

Forty-three patients who underwent facial reanimation surgery with free functional muscle transfer between March 2015 and July 2017 at our medical center in Seoul, Korea, were identified through a retrospective review of medical records. All operations were performed by a senior surgeon (T.S. Oh). For a comparative evaluation of surgical outcomes patients were divided into two groups: a control group with 20 patients who underwent conventional procedures and the NLF group with 23 patients who underwent our NLF reset procedure. The surgical details of the NLF procedure are described below. In the control group, the medial part of the gracilis muscle anchoring was used for direct muscle anchoring. Perioral fixation was performed through superficial musculoaponeurotic system dissection or through incision along the redline (the border between the dry and wet mucosa of the lip).

Preoperative and postoperative photographs were taken in the resting and smiling states. The photographs were analyzed using FACEgram (Facial Assessment by Computer Evaluation), a software program that calculates the smile excursion and the asymmetry index. Smile excursion is defined as the distance from the maximum oral commissure (point A) to the intersection point of the vermilion border of the lower lip and the perpendicular midpupillary line (point B). Asymmetry index is defined as the ratio (affected-to-healthy) of the horizontal length of the oral commissure (Fig. 1). The 3D facial volume analysis was performed using 3D photogrammetry. 3D photographs of all selected patients were taken using a Morpheus® 3D, LED-based, white-structured-light scanner (Morpheus Co. Ltd., Seongnam City, Gyunggi-do, Korea), which divides the length of the face automatically into three parts (upper, middle, and lower face) and calculates the 3D volume. This enables volumetric comparison between the affected and healthy sides, preoperatively and postoperatively (Fig. 2). For the intended usage of the photographs, photographic authorization and release consent were obtained from the patients. This study conformed to the principles of the Declaration of Helsinki and was approved by our institutional review board.

2.2. Surgical procedure (Fig. 3)

1. The affected palsy side showed soft tissue ptosis and decreased muscle tone.
2. Before general anesthesia induction, the NLF was marked on the affected side, corresponding to that of the healthy side, using a flexible, slender wire, with the patient in the sitting position. The sitting position is essential to include the effects of gravity.
3. After marking the mirrored NLF on the resting face, the midcheek soft tissue was raised and pulled down by hand. The marking at this stage resembled the preoperative marking for a double-eyelid operation. The patient was made to blink several times to predict the fold position in the closed and open eye states. The upper lateral soft tissue was manipulated by hand to simulate smiling facial reanimation by lifting the midcheek up and down (Video 1).

Fig. 1. Objective outcome assessment of patients using FACEgram. The facial midline, defined as the midpupillary line, is indicated in dark blue. Both vertical lines through the oral commissure ends are shown in light blue. Smile excursion was defined as the direct distance from the maximum oral commissure (point A) to the intersection point of the vermilion border of the lower lip and the perpendicular line of the midpupillary line (point B). The asymmetry index was defined as the ratio between the horizontal lengths of the affected side (D) and the healthy side (C). All measurements were evaluated both in the resting and smiling states. (a) Smile excursion in the resting state. (b) Asymmetry index in the resting state.

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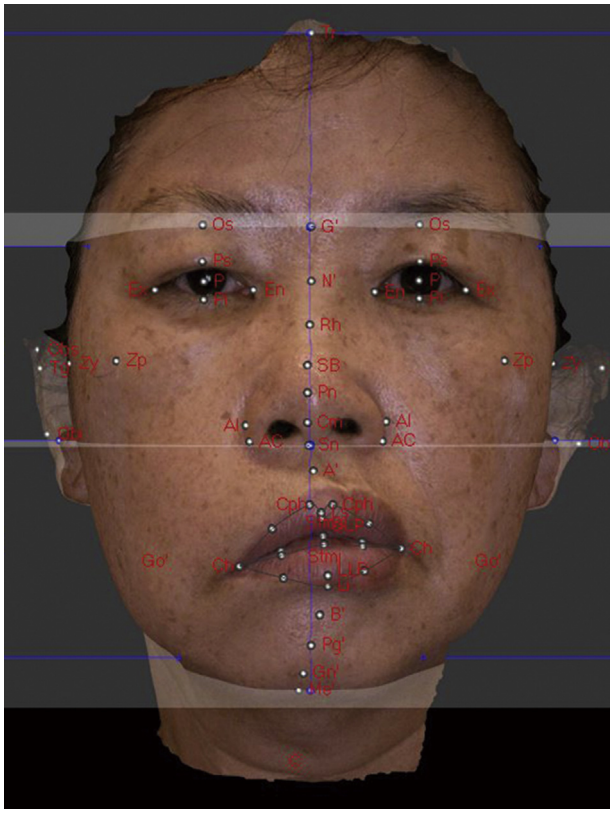

Fig. 2. Three-dimensional volumetric analysis using Morpheus®. Three-dimensional (3D) photographs of the patient were taken while sitting in a neutral position. The device captured three images (frontal, left, and right oblique views) from which 3D reconstructed photographs could be generated. The user can define facial landmarks (white dots), and the device can provide three volumetric proportions. Through four horizontal planes that pass through the trichion, glabella, subnasale, and menton, the facial volume is divided into upper, middle, and lower parts.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.jcms.2020.01.001.

4. After completion of the previous step, two lines were observed in the mirrored NLF. One of the lines was the directly mirrored NLF and the second was the expected lifted line. These two lines comprised the newly designed NLF, to be connected in a semicircular shape.
5. The design of the semicircular shape was followed by de-epithelialization.
6. An incision was made from the lateral side; dissection was performed toward the medial side; and the medial dermal flap was elevated.
7. The elevated dermal flap was mobilized and hung toward the superolateral side.
8. Suturing the dermal flap was the key procedure at this stage. The dermal flap was positioned and fixed superiorly and laterally so that the midcheek appeared bulky and raised. The large lower-facial volume was able to slide upwards medially, resulting in deeper dimpling. After closure of the dermal flap, the new NLF was visualized medially on the affected side and repositioned laterally, with the soft tissue appearing bulkier and raised.
9. The NLF on the affected side was consequently symmetrical to the other side, with the lifted soft tissue helping to increase facial muscle tone following facial reanimation surgery. This technique was performed at the secondary stage in patients who had already undergone free muscle transfer or at the same stage in those undergoing facial reanimation surgery.

2.3. Case

A representative case was a 54-year-old female patient with complete left-sided facial palsy after schwannoma excision. Platinum insertion for eye closure was performed first, followed by double-innervated functional gracilis muscle transfer after 4 months. At the same stage, we performed the NLF reset technique to enhance the midface lift. Preoperatively, the patient had visible perioral wrinkling and disappearance of the NLF. Compared with the right side, the palsy side of her face showed more soft tissue drooping towards the lower part, resulting in a relatively larger amount of soft tissue in the lower face than in the middle face (Fig. 4a and b).

One medial marking line on her left cheek denoted the mirrored NLF from the right side, while a semicircular lateral marking line denoted the expected animation line for the new NLF. After de-epithelialization from the lateral to the medial side, the dermal skin flap was freely mobilized. As the method of fixing this dermal flap is responsible for making a new smile, we sutured this flap superiorly and laterally. Thus, the drooped lower facial volume could be transferred towards the upper side (Fig. 4c). A 10-cm gracilis muscle flap with obturator nerve was harvested from the left leg. The facial artery and vein were used as the recipient vessels and were anastomosed in an end-to-end fashion (Fig. 4d). Immediately postoperatively, the patient's NLF looked symmetrical on the left side (Fig. 4e). Postoperatively, her left-sided NLF mirrored the healthy side, except for the operation scar. The new NLF thus took the role of creating a more natural smile than that present preoperatively (Fig. 4f and g).

2.4. Statistical analyses

All statistical analyses were performed using SPSS 19.0 (IBM SPSS Inc., Chicago, IL, USA).

Paired t-tests were used to compare the preoperative and postoperative smile excursion distances and the asymmetry index. Repeated 3D photogrammetric values were compared using paired t-tests. Values of $p < 0.05$ were considered indicative of a statistically significant difference.

3. Results

Forty-three patients were included in this study. Of these, 20 underwent conventional free gracilis muscle transfer without NLF reset (control group) and 23 additionally underwent the incisional NLF reset technique (NLF group). The patients' demographic and clinical data are presented in Table 1. The mean patient age was 39.07 years in the control group and 47.95 years in the NLF group, and the male-to-female ratios were 9:11 and 11:12, respectively. The mean follow-up period was 22.2 months in the control group and 15.25 months in the NLF group.

Using FACEgram, we evaluated oral commissure excursion and symmetry at rest and during smiling. The NLF group showed improved postoperative smile excursion in both the resting and smiling states (mean difference: resting 5.76 mm vs smiling 5.99 mm). The NLF group had a significantly larger postoperative mean excursion at rest (control 25.32 ± 2.80 mm vs NLF 27.42 ± 3.60 mm; $p = 0.047$). In the smiling state, there was no significant difference between the two groups (Fig. 5).

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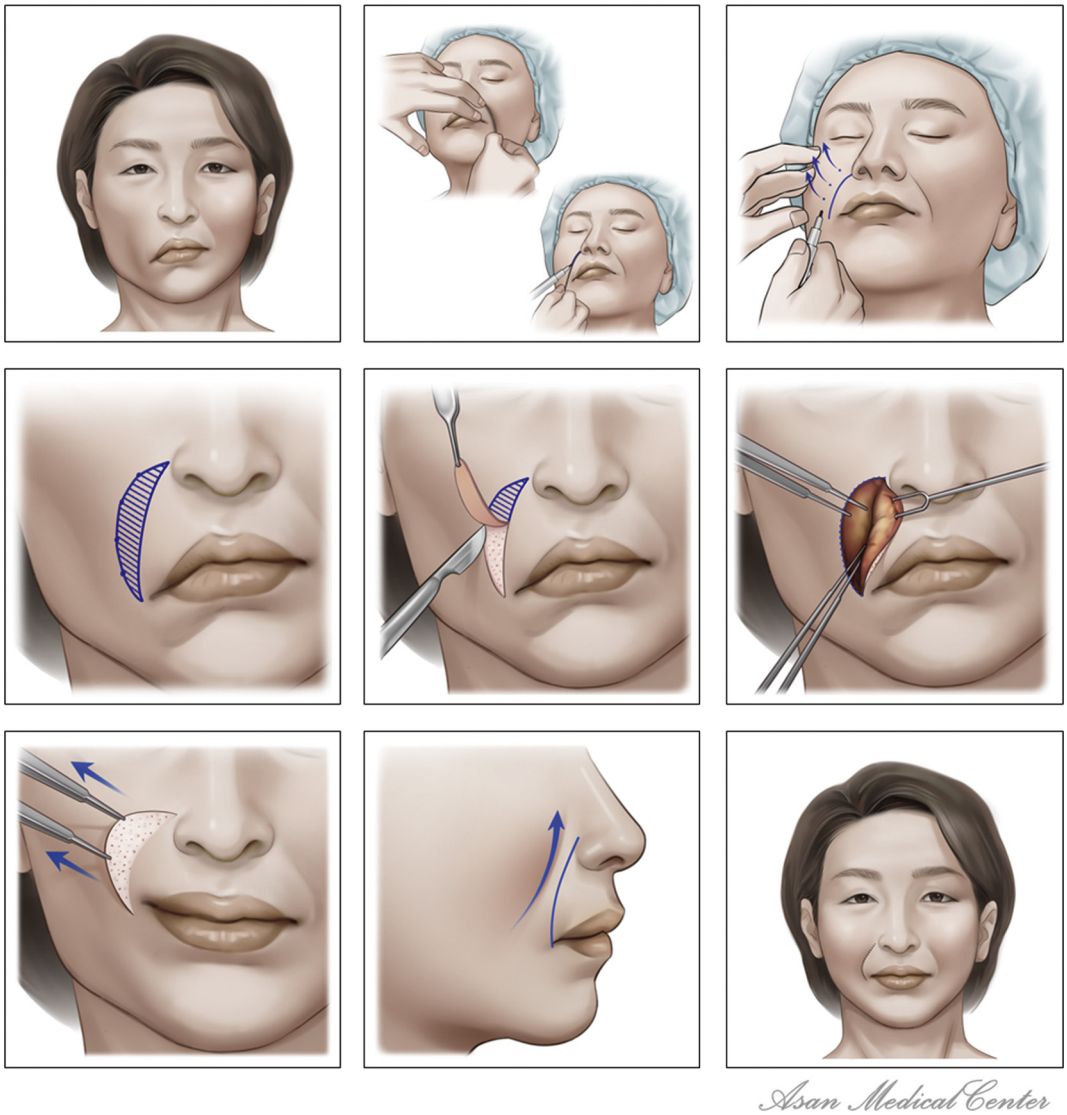

Fig. 3. Surgical procedure for the nasolabial fold reset technique to enhance midface lifts for facial reanimation.

The asymmetry index — the mean horizontal length ratio (affected-to-healthy) — revealed better symmetry in the NLF group (resting 1.05 ± 0.22, smiling 0.97 ± 0.19; $p = 0.201$). Before the procedure, a significant difference was observed between the two groups in terms of symmetry, with more patients in the NLF group showing asymmetry. After the procedure, no significant difference was observed between the two groups. This implied successful surgical outcomes in the NLF group (Fig. 6).

3D facial volumetric analysis showed concentrated facial volume in the lower face preoperatively. Both groups showed paralyzed facial characteristics, including soft tissue descent. In the NLF group, this volume difference was noticeably corrected, especially in the middle face (preoperative difference 43.63 ± 46.92 cm^3 vs postoperative difference 10.97 ± 1.71 cm^3). Postoperatively, the 3D midface volume difference was significantly lower in the NLF group (control 27.31 ± 21.52 vs NLF 10.97 ± 1.71, $p = 0.030$), probably as a result of the repositioning of the middle portion of the face (Fig. 7).

4. Discussion

Advances in facial reanimation surgery facilitate the maximal facial muscle contraction associated with smiling. Varied surgical options, such as nerve graft, muscle transposition, and free flap, are available for this procedure (Tate and Tollefson, 2006). Free muscle transfer has been the mainstream surgical procedure, with research efforts focusing on enhancing its efficacy (Klebuc, 2011; Terzis et al., 2000). Masseter-to-facial nerve transfer and interposition grafts have achieved improved surgical outcomes thus far; however, from our experience spanning the last 7 years, reinforcement of muscle power does not guarantee aesthetic satisfaction (Supplementary Fig. 1). At our institution, double innervation in free muscle transfer through facelift incision has obtained good coordination with facial muscle expression. However, even after a successful reconstruction, the clenching strong force involved in this procedure can lead to a very unnatural appearance. With respect to aesthetic aspects in this situation, powerful muscle contraction restoration is

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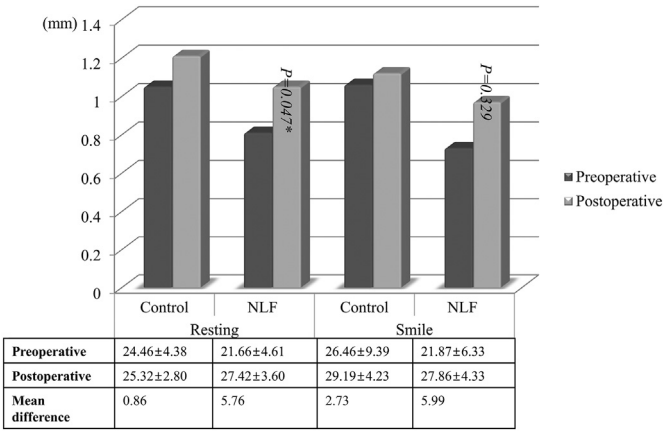
Fig. 4. Representative case of our technique: double-innervated functional gracilis muscle transfer using the new nasolabial fold reset technique. (a) Preoperative resting state. (b) Preoperative smiling state. (c) Design and intraoperative facial animation. (d) Flap insetting. (e) Immediate postoperative photograph. (f) Postoperative resting state. (g) Postoperative smiling state.

Table 1
Patient and operative characteristics.

	Control	NLF
Age, years	39.07	47.95
n (male/female)	20 (9/11)	23 (11/12)
Follow-up time, months (range)	22.2 (13.7–33.8)	15.25 (11.9–15.2)
Duration of paralysis, years (range)	18.5 (11–27)	13.0 (10–33)

NFL: nasolabial fold.



	Resting		Smile	
Preoperative	24.46±4.38	21.66±4.61	26.46±9.39	21.87±6.33
Postoperative	25.32±2.80	27.42±3.60	29.19±4.23	27.86±4.33
Mean difference	0.86	5.76	2.73	5.99

Fig. 5. Preoperative and postoperative smile excursion comparison. *NLF: nasolabial fold.

considered not useful. In our study, we focused on the anatomy of the NLF to find an alternative solution to this problem.

The NLF is not merely a cutaneous depression. In the mechanism of smiling, the deep-seated NLF is considered a fixed point for smile initiation, and is comprehensively connected to the facial muscles (Zufferey, 1992). This explains the midface soft tissue drooping related to smile initiation in elderly patients (Jost et al., 1987). The effect of gravity cannot be ignored, as is involved in the interaction between the superficial muscle, adynamic cheek mass, and deep-plane adynamic muscle (Barton, 1992). Therefore, trials on facial reanimation surgery using the NLF have been performed. This technique was proposed by Labbé, who reported on lengthening temporalis myoplasty in the treatment of facial paralysis (Labbé, 1997; McLaughlin, 1953). He used the total temporalis muscle by transferring the muscle toward the coronoid process, which can be anchored around the lip. In this procedure, a drastic incision around the lip is required to provide solid, sling-related lip reanimation that enables transfer of the mobile coronoid point to the lip. In the

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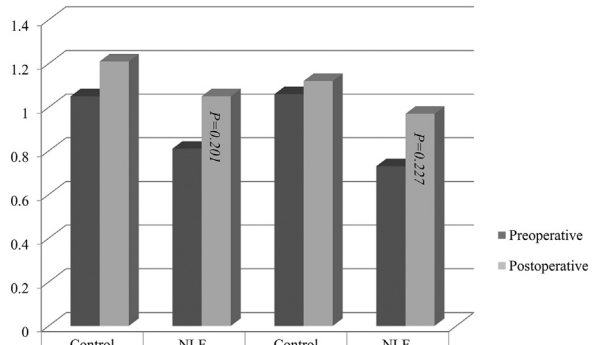
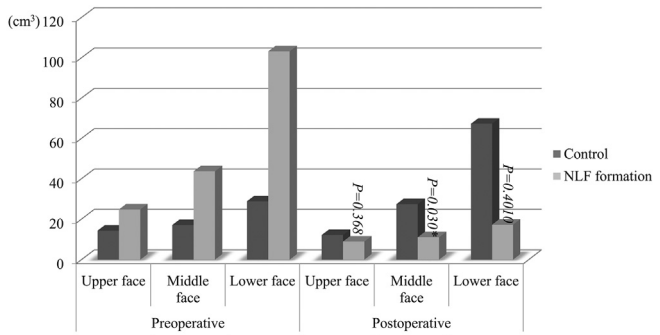


	Resting		Smile	
Preoperative	1.05±0.20	0.81±0.20	1.06±0.59	0.73±0.25
Postoperative	1.21±0.54	1.05±0.22	1.12±0.52	0.97±0.19
Mean difference	0.16	0.24	0.06	0.24

Fig. 6. Preoperative and postoperative asymmetry index comparison: mean horizontal length ratios (affected-to-healthy). *NLF: nasolabial fold.

context of this procedure, the improved facial animation can be attributed to a more direct link to the perioral muscle.

In this study, we proposed an NLF reset surgical technique for enhancing facial reanimation using free muscle transfer reconstruction. Inspired by the Labbé technique, an incision in the NLF is necessary, with the dermal flap fixation technique essential for obtaining an effective midface lift in facial reanimation surgery for the elderly or patients with heavy-cheek facial paralysis. When combined with the gracilis muscle flap, proper dermal flap fixation causes the mobilized dermal flap to lie over the gracilis muscle. It should be noted that functional considerations need to accompany anatomic complexity. Consequently, in this procedure, lateral reinforcement of the gracilis flap and lip eversion are performed in order to gain medial perioral reanimation. The medial and lateral segments of the NLF have been described in cadaveric studies (Latham and Deaton, 1976; Lightoller, 1925). The action of direct dermal flap anchoring through the modiolus to influence gracilis muscle contraction can be explained by these segments. The medial segment acts as a direct labial tractor and the lateral segment acts as an indirect labial tractor. Although an acceptable scar remains, we recommend our procedure for patients with midcheek drooping, such as middle-aged patients with paralysis. For young patients who do not have any soft tissue problem, instead of an incisional NLF we recommend another incision — the red line incision — which creates a hideable scar within the vermilion.



	Preoperative			Postoperative		
Control	14.27±7.98	17.04±12.59	28.75±18.52	12.09±5.14	27.31±21.52	67.24±95.06
NLF	24.72±24.42	43.63±46.92	103.14±93.43	8.88±4.55	10.97±1.71	17.21±2.86

Fig. 7. Preoperative and postoperative three-dimensional volumetric analysis comparison.

Our study results showed a significant increase in smile excursion in the resting state. In the smiling state, no significant difference between the control and the NLF group was observed, implying the same degree of functional outcome in reanimation. However, the NLF group showed better facial animation in the resting state. A better outcome in the resting state is desirable because, generally, this result is directly related to patient satisfaction. Our proposed new technique therefore seems to offer more benefits compared with the functionally inferior conventional techniques.

The asymmetry index was observed to have improved postoperatively in the study group. As a limitation of the retrospective study design, a higher proportion of patients with severe asymmetry was unintentionally included in the NLF group by the senior operator. However, the postoperative results showed a similar degree of enhanced symmetry in the control group. Given the higher proportion of patients with asymmetry in the NLF group, this level of symmetry improvement could be attributed to the new technique. Lastly, 3D volume difference analysis between the healthy and affected sides demonstrated effective midface lifting through the NLF reset technique. In paralyzed patients, the soft tissue characteristics include ptosis, drooping lip, absence of nasolabial deepening, and decreased muscle tone. Improvement in these characteristics could be observed because the concentrated lower facial volume was redistributed toward the midface, which, in turn, contributed to midface symmetry (Fig. 8).

In terms of aesthetic considerations, we wish to offer a few surgical tips for the NLF reset technique (Supplementary Fig. 2). There are various types of NLF, including convex, concave, and straight (Rubin, 1974; Rubin et al., 1989). In our procedure, we used a flexible, slender wire to allow the NLF on the palsy side to mirror that on the healthy side. However, for aesthetic reasons, facial fat distribution has to be considered, which varies according to age. In particular, middle-aged women have decreased skin density over the fold and excessive fat deposits lateral to the fold. This procedure is similar to the excision of redundant skin in blepharoplasty, when a new lid fold is re-defined. Such aesthetic considerations could offer higher chances of achieving a successful smile. Through the NLF technique, a typically deep setting of the new NLF can be created to yield a natural appearance. The correct design of a new NLF is important; this includes deciding on its starting point. If too lateral or too medial, this can produce a distorted smile. Simply revising the starting point can result in better outcomes.

The incisional approach and the resulting scar may create concerns. Temporalis muscle lengthening is commonly accompanied by perioral incision, for which trials of methods to avoid scarring, including an endoscopic approach, have been performed (Contreras-Garcia et al., 2003). Many surgeons are apprehensive about creating additional scars on a patient's face. To address this problem, an understanding of the biomechanics of the NLF is required. Scar hypertrophy can occur through forceful pulling of the incision. To prevent this, eversion of the tissue flap during wound closure is emphasized, with the 'eversion force' — the forces acting on the NLF — being concentrated in one direction.

The mirroring method we used to design the new NLF incision included reflection of vectors from the contraction of the contralateral zygomaticus major muscle along with the new NLF line (Boahene, 2013; Gordon et al., 1966). The moment arm of muscle contraction is fundamental for the direction of action. This is defined as a vector along the perpendicular line (Brand et al., 1981). The result is that the new NLF has a congregating force toward the upper side of the nasal alar. With this approach, scar hypertrophy is not a concern because the scar disappears with time and is comparable to the NLF deepening on the healthy side.

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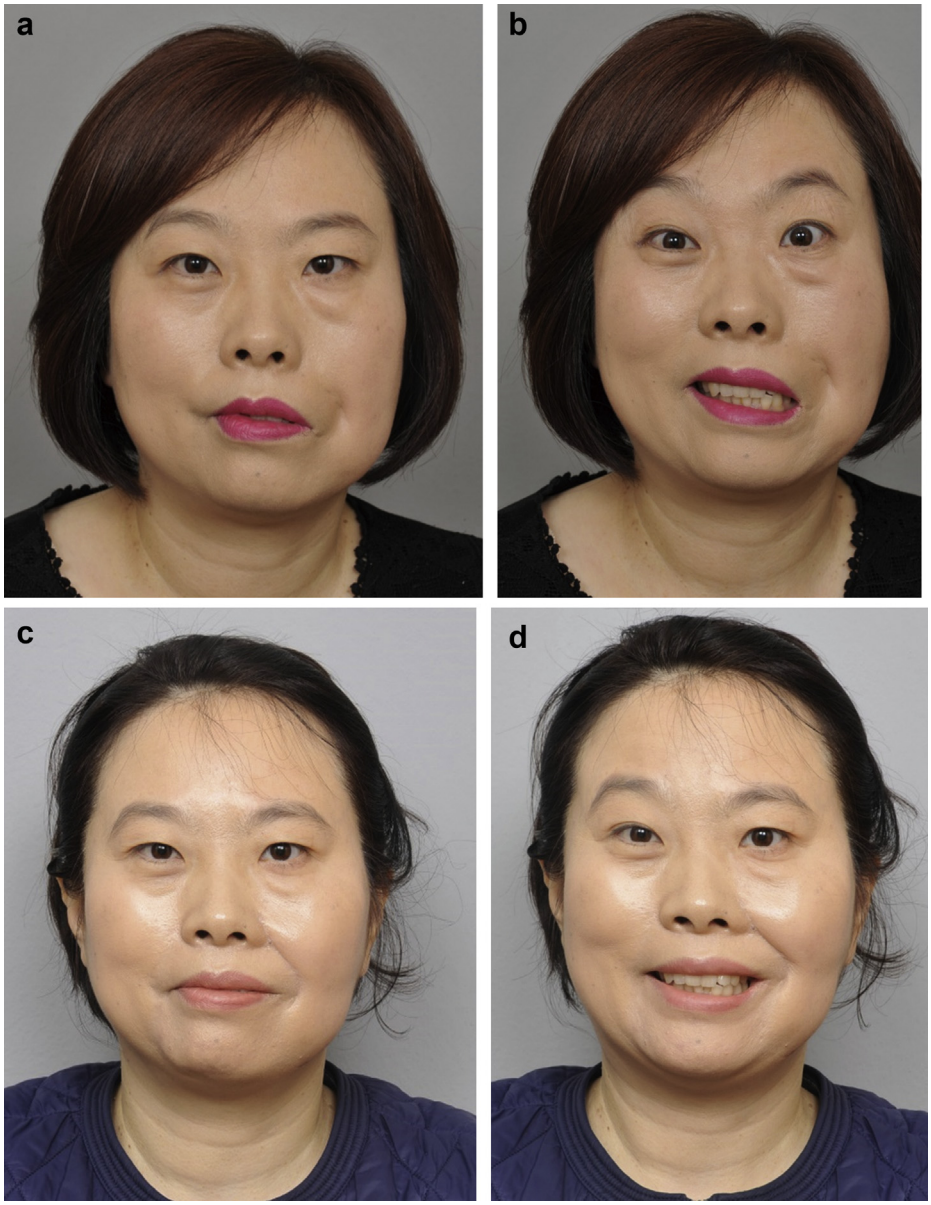

Fig. 8. A 48-year-old female patient with incomplete left-sided facial palsy starting from age 3 years. She had undergone nerve grafting 15 years previously and tendon transfer 8 years previously at another institution. Preoperatively, her resting and smiling facial appearances appeared unnatural, with deep dimpling on the left side of her face disturbing the facial expression. During treatment at our institution she underwent double-innervated functional gracilis muscle transfer with the nasolabial fold reset technique. In the postoperative photographs and video her resting state improved and appeared more natural. Moreover, the middle portion of her face appeared to have more volume and to be more symmetrical with the healthy side. (a) Preoperative resting state. (b) Preoperative smiling state. (c) Postoperative resting state. (d) Postoperative smiling state.

5. Conclusions

This study introduced an NLF technique in facial reanimation surgery. Unresolved soft tissue redundancy in functional muscle transfer requires a midface lift for natural facial expression. Our method, forming a with a new, mirrored NLF, demonstrated effectiveness with an improved surgical outcome. Bimanipulation of muscle and soft tissue in one stage might underlie a new paradigm in facial palsy surgery.

Ethical approval

This study was approved by the institutional review board of Asan Medical Center (approval no. 2019-0166) and performed in accordance with the principles of the Declaration of Helsinki.

Funding

None.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2020.01.001.

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