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Facial reanimation using free partial latissimus dorsi muscle transfer: Single versus dual innervation method

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A B S T R A C T

The aim of the present study was to analyze the consequences of partial free latissimus dorsi muscle flap with nerve splitting technique (Partial LD transfer) for facial reanimation and compare outcomes according to innervation method (singer versus dual innervation).

Patients with complete unilateral facial paralysis underwent either the single (ipsilateral masseteric nerve only) or dual (ipsilateral masseteric nerve plus contralateral buccal branch of the facial nerve) nerve innervation method for facial reanimation. An assessment was carried out to compare the outcomes between the single and dual innervation.

Total of 21 patients were involved in this study. In the single innervation group, 7 out of 8 patients developed a voluntary smile. However, none were able to achieve a spontaneous smile. On the other hand, 9 out of 13 patients developed a voluntary smile and 3 out of 13 patients achieved a spontaneous smile. The mean increases of smile excursion assessed by Emotrics software and Terzis grades showed no significant differences between two groups.

Within the limitations of the study it seems that partial LD transfer approach utilizing the dual innervation method has a positive effect on achieving a spontaneous smile and could be a valuable option for facial reanimation.

1. Introduction

Facial paralysis disrupts the innate connection between mimetic muscles and emotions. This functional impairment poses a barrier to social interaction and consequently decreases quality of life (*Nellis* et al., 2017; Guntinas et al., 2007; *Lassaletta* et al., 2006). In the last decade, free functional muscle transfer has been the gold standard treatment approach for chronic facial paralysis. Until now, numerous reconstruction options, including options involving two mainstream donor muscles (gracilis muscle and latissimus dorsi muscle), have been introduced (*Dong* et al., 2018; *Bianchi* et al., 2016; *Bae* et al., 2006; *Manktelow* et al., 2006; *Harii* et al., 1998; *Cuccia* et al., 2005; *Biglioli* et al., 2012a).

As advances in the field of facial reanimation have been made globally, recovering a spontaneous smile is one of the most important goals for patients with facial paralysis. To restore a spontaneous smile, physicians have used dual innervation methods that combine the ipsilateral masseteric motor nerve and contralateral normal facial nerve branch in a single free muscle flap (*Cardenas-Mejia* et al., 2015; *Biglioli* et al., 2012b; *Sforza* et al., 2015; *Okazaki* et al., 2015; *Dusseldorp* et al., 2019). However, controversies still exist regarding whether the dual nerve innervation method is superior to the method involving a single motor nerve (the masseteric nerve or hypoglossal nerve) in terms of the outcomes of smile restoration after reanimation surgery (*Manktelow* et al., 2006; *Lifchez* et al., 2005).

Therefore, it was the aim of the study to compare outcomes between the single and dual innervation methods.

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2. Patients and methods

The study was approved by the Institutional Review Board of our institution (IRB No. 1807-143-961) and was performed in accordance with the Declaration of Helsinki. In the study, we examined patients with unilateral facial paralysis who underwent a reanimation procedure using the partial LD transfer method between March 2016 and February 2019. All patients who were diagnosed with complete unilateral facial paralysis (House-Brackmann grade 6) underwent either the single (ipsilateral masseteric nerve only) or dual (ipsilateral masseteric nerve plus contralateral buccal branch of the facial nerve) nerve innervation method for facial reanimation. The indications for using the single innervation method were failure to find an appropriate contralateral buccal branch of the facial nerve and a desire for a less invasive procedure to avoid injury to the normal hemiface. Patients with a follow-up period of less than 12 months and those who underwent previous facial reanimation surgery were excluded from data collection. A retrospective chart review for data, including age, sex, duration of paralysis, etiology, and postoperative outcomes was performed. All patients underwent a rehabilitation protocol starting 1 month after the surgery. The protocol began with the patient standing in front of a mirror for 30 min per day and smiling with their teeth clenched and then smiling without their teeth clenched.

2.1. Surgical technique

Patients were placed in a semi-lateral decubitus position with the paralyzed side up. A modified Blair incision was made in the temporal region bypassing the tragus and going under the earlobe. The incision extended 6–8 cm into the cervical region along a skin crease 3 cm caudal to the inferior mandibular border. An anterior skin flap was elevated from the superficial muscular aponeurotic system (SMAS) to access the lower two-thirds of the face. After exposing the facial vessels, the masseteric nerve was identified within the muscle by using the zygomatic arch and the tragus as surgical landmarks. On the healthy side of the face, a linear incision was made along the nasolabial fold. Dissection was performed for exploration of the buccal branch of the facial nerve. The distance between the zygomatic arch and the oral commissure was measured to determine the size of the muscle flap to harvest.

A latissimus dorsi neurovascular muscle flap was simultaneously harvested from the ipsilateral back lesion using a two-team approach. A zigzag incision was made from the axilla to the posterior axillary line. After subcutaneous dissection, the anterior border of the latissimus dorsi muscle was identified. Dissection continued until the hilum and bifurcation points of the descending branch and transverse branch of the thoracodorsal vessels and nerves were reached. After marking the required muscle flap, additional dissection along the distal end of the muscle segment was performed to isolate the distal stump of the descending branch of the thoracodorsal nerve (TDN). After separating the muscle flap, the interfascicular nerve splitting method was performed under loupe magnification, as discussed in a previous study (Fig. 1). The flap pedicle was divided after twitching the muscles of both the descending branch (proximal and distal) and transverse branch of the TDN, and dominance was confirmed by a nerve stimulator (Fig. 2 and Online Video 1).

Supplementary video related to this article can be found at doi:10.1016/j.jcms.2022.09.001

The harvested neurovascular muscle flap was transferred into the face pocket, and end-to-end vascular anastomosis was performed between the thoracodorsal vessels and facial vessels. In the dual innervation group, end-to-end neural anastomosis was carried out between the distal portion of the descending branch of the TDN

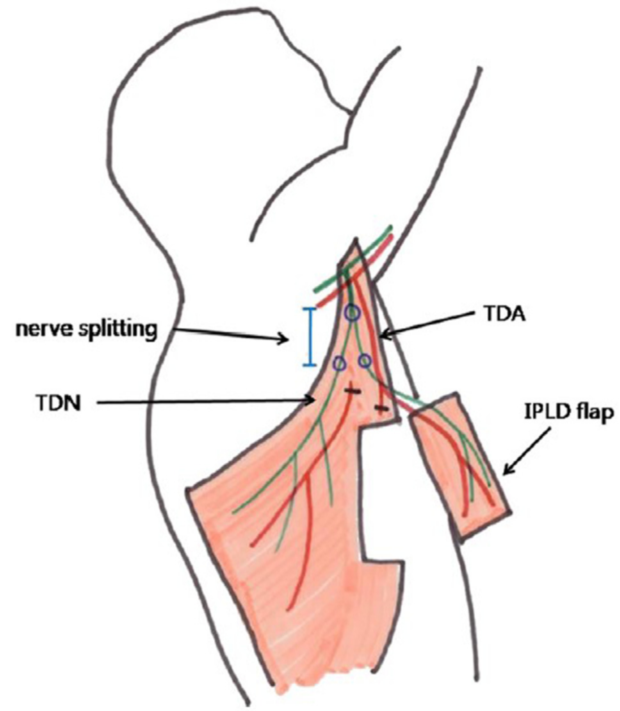

Fig. 1. Interfascicular nerve splitting method was performed to preserve the transverse branch of the TDN. The schema from (*Kwon* et al., 2011).

and the ipsilateral masseteric nerve. Additional end-to-end neural anastomosis was carried out between the proximal portion of the descending branch of the TDN and the contralateral facial nerve branch (Fig. 3). On the other hand, in the single innervation group, end-to-end neural anastomosis was carried out between the proximal portion of the descending branch of the TDN and the ipsilateral masseteric nerve.

After flap placement in the facial pocket, each end of the muscle was sutured to the modiolus and the periosteum of the zygomatic arch. The skin flaps were closed, and drains were inserted.

2.2. Outcome measures

Each patient underwent preoperative and postoperative photography, and an animation video was taken 12 months after surgery. Smile outcomes were assessed using Hadlock's smile measurement on the lip excursion scale with Emotrics software (Sir Charles Bell Society) (*Bray* et al., 2010; *Guarin* et al., 2018) (Fig. 4). In addition, an esthetic and functional grading system (*Terzis and Noah, 1997*) (Table 1) was used for smile evaluation. The questionnaire was given to all patients to evaluate the types of smiles (voluntary or spontaneous) and the timing of the first muscle movement, and was administered when they visited the outpatient clinic at 3, 6, 9, and 12 months after surgery. At the outpatient clinic, two methods were used to quantify spontaneous smiling. First, the patients were asked to smile with and without clenching their teeth, and the video were recorded. Three blind clinicians who specialized in plastic surgery evaluated the types of smiles (voluntary vs. spontaneous). If all three investigators' assessment results were not the same, the outcome was marked as “not assessable” and patients were asked to visit again 1 month later. Second, At 12 months after surgery, blinded assessor analyzed Spontaneous Smile Assay (SSA). The SSA was performed after

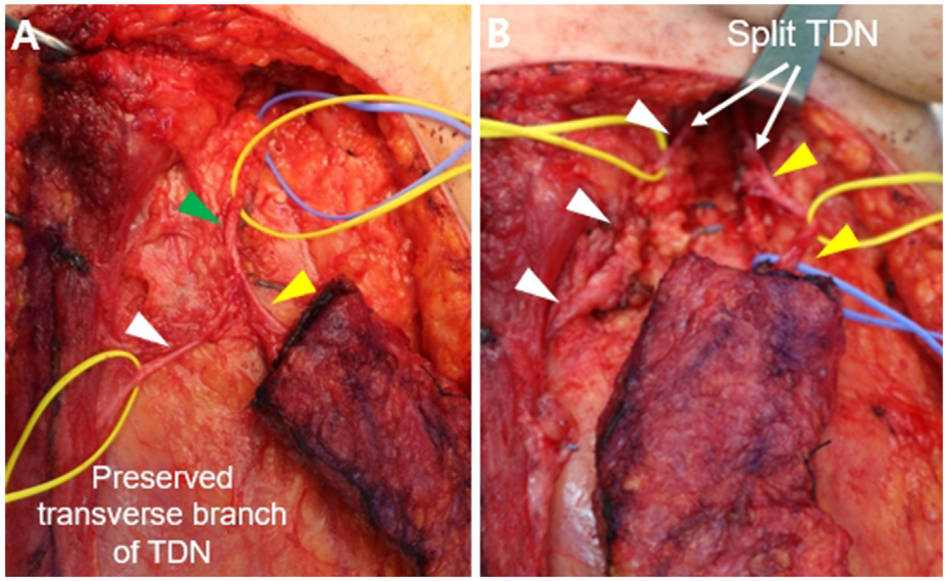

Fig. 2. Intraoperative photographic findings of nerve splitting method. (A) Preservation of transverse branch of TDN. (B) After interfascicular splitting (online Video 1.).

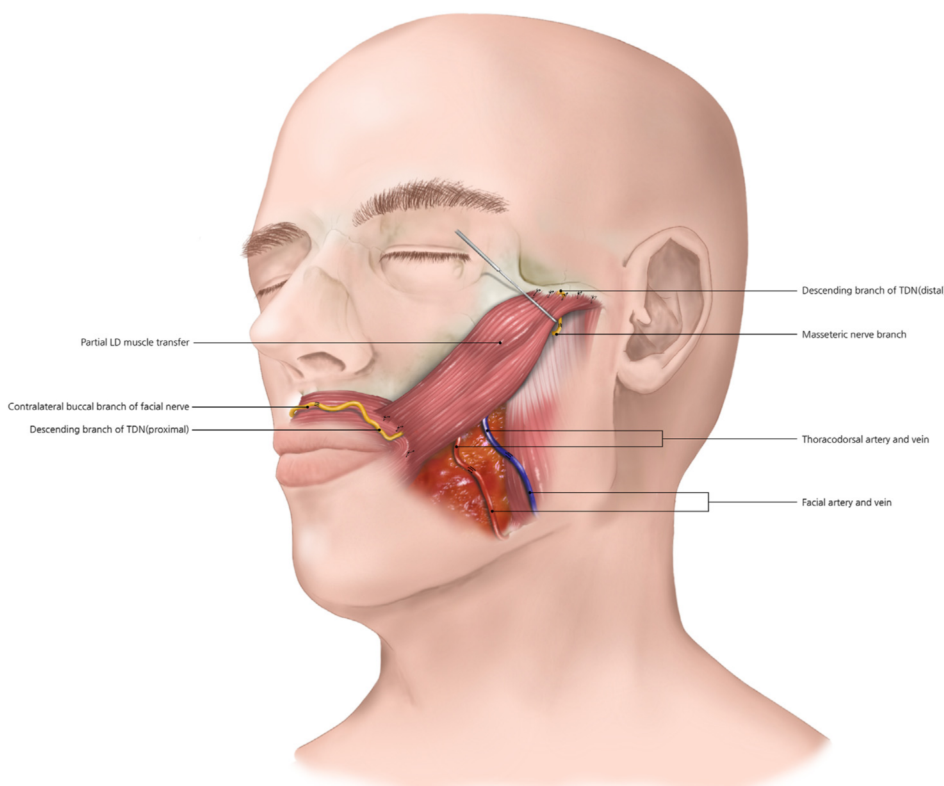

Fig. 3. The schema of novel dual innervation method utilizing TDN for facial reanimation.

obtaining videos of spontaneous smiles from patients by watching humorous video clips (*Iacolucci* et al., 2015; *Dusseldorp* et al., 2019).

For statistical analysis, a comparison between the single and dual innervation methods for spontaneous smile recovery was conducted using the Mann-Whitney *U* test. SPSS v26.0 (IBM Corp., Armonk, NY, USA) was used to analyze the results and perform all statistical tests. Significance was set at a *p*-value <0.05.

3. Results

Of the 21 patients who underwent facial reanimation using partial LD transfer, 8 underwent the single innervation method and 13 underwent the dual innervation method. The mean age of the patients was 41.2 years (range: 20–56 years) in the single innervation group and 41.5 years (range: 18–65 years) in the dual

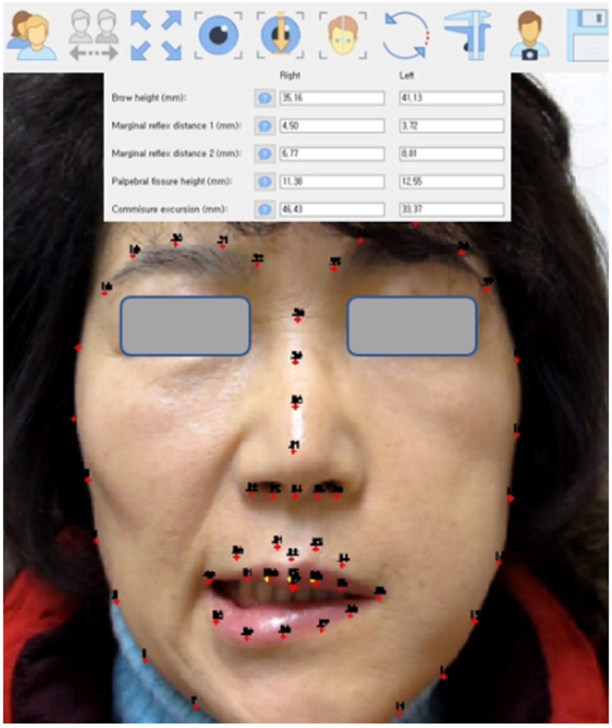

Fig. 4. Patient example of lip excursion evaluation using Emotrics software.

Table 1
Esthetic and functional grading system used for smile (Terzis and Noah, 1997)

Grade	Result	Description
1	Poor	Deformity, no contraction
2	Fair	No symmetry, minimal contraction
3	Moderate	Moderate symmetry and contraction
4	Good	Symmetry, nearly full contraction
5	Excellent	Symmetrical smile with teeth showing, full contraction

innervation group. The distribution of sex was 4 men and 4 women in the single innervation group and 6 men and 7 women in the dual innervation group. When comparing the duration of paralysis between the innervation groups, the single innervation group had a lower duration before receiving reanimation surgery (8.1 years vs. 11.5 years). The most common etiology was brain tumor in the single innervation group and parotid tumor in the dual innervation group (Table 2).

Table 2
Patients' demographics of Split LD transfer with nerve splitting method.

Surgical technique	Single innervation	Dual innervation	Total
Number of patients	8	13	**21**
Age			
Mean	41.2	41.5	**41.4**
Range	20–56	18–65	**18–65**
Sex			
Men	4	6	**10**
Women	4	7	**11**
Duration of paralysis, years			
Mean	8.1	11.5	**10.2**
Range	2–20	2–37	**2–37**
Etiology of paralysis			
Brain tumor	4	2	**6**
Parotid tumor	1	4	**5**
Trauma	1	3	**4**
Vestibular schwannoma	–	3	**3**
Chronic otitis media	–	2	**2**
Bell's palsy	–	2	**2**

According to clinician-assessed spontaneity in the single innervation group, 7 out of 8 patients developed a voluntary smile. However, none were able to achieve a spontaneous smile (Fig. 5 and Online Video 2). On the other hand, in the dual innervation group, 9 out of 13 patients developed a voluntary smile and 3 out of 13 patients achieved a spontaneous smile (Fig. 6 and Online Video 3).

Supplementary video related to this article can be found at doi: 10.1016/j.jcms.2022.09.001

The SSA was performed in 7 (88%) of 8 patients treated with single innervation method. Of these, no patients generated a s spontaneous during the video that could be analyzed. On the other hand, SSA was performed in 10 (77%) of 13 patients treated with dual innervation group. Of these, 3 of 10 patients (30%) generated a spontaneous smile during the video. The median (IQR) percentage of synchronous oral commissure movements in these patients was 38.1%.

When analyzing smile characteristics, the mean onset of a voluntary smile was 5.1 months in the single innervation group and 3.7 months in the dual innervation group. A spontaneous smile developed in 10.3 months after reanimation surgery only in the dual innervation group. The mean differences in smile excursion on the paralyzed side from the preoperative status were +5.8 mm in the single innervation group and +6.0 mm in the dual innervation group. Furthermore, the mean quantitative differences using Terzis grades were +2.5 in the single innervation group and +2.8 in the dual innervation group. However, both findings showed no statistical significance ($p = 0.88$ and 0.35, respectively) (Table 3).

4. Discussion

Improvement in quality of life is a global issue, and facial reanimation surgery has shown promise in the field of plastic and reconstructive surgery. Among various reconstruction options, free neurovascular muscle transfer has been regarded as the gold standard approach for chronic facial paralysis. In particular, acquiring a spontaneous smile in advance of a voluntary smile is still a topic of interest. To overcome a voluntary smile motored by the ipsilateral masseteric nerve, physicians have performed various dual innervation methods by combining an additional neural source from the contralateral normal facial nerve branch in a single free muscle flap.

Biglioli et al. (2012b) transposed a free gracilis muscle flap, in which the obturator nerve was innervated with the masseteric nerve (end-to-end) and the contralateral buccal branch of the facial nerve (end-to-side), using an interpositional sural nerve graft. All 4 patients achieved a spontaneous smile within approximately 7.2 months after the surgery. However, by adding nerve coaptation for the interpositional nerve graft, the recovery of function could be delayed and become more uncertain. Moreover, donor site morbidity could increase with the use of two sites (inner thigh and lower leg).

Several previous studies have reported using the dual innervation method for facial reanimation. *Cardenas-Mejia* et al. (2015) suggested a similar procedure as that mentioned by Biglioli et al. (*Biglioli* et al., 2012), except they performed end-to-end obturator nerve anastomosis with the masseteric nerve rather than using an interpositional sural nerve graft by coapting the contralateral buccal branch of the facial nerve in an end-to-end fashion. However, the concerns of utilizing additional interpositional graft coaptation and donor site morbidity were not addressed.

Okazaki et al. (2015) utilized two segments of the latissimus dorsi muscle flap containing both the transverse and descending

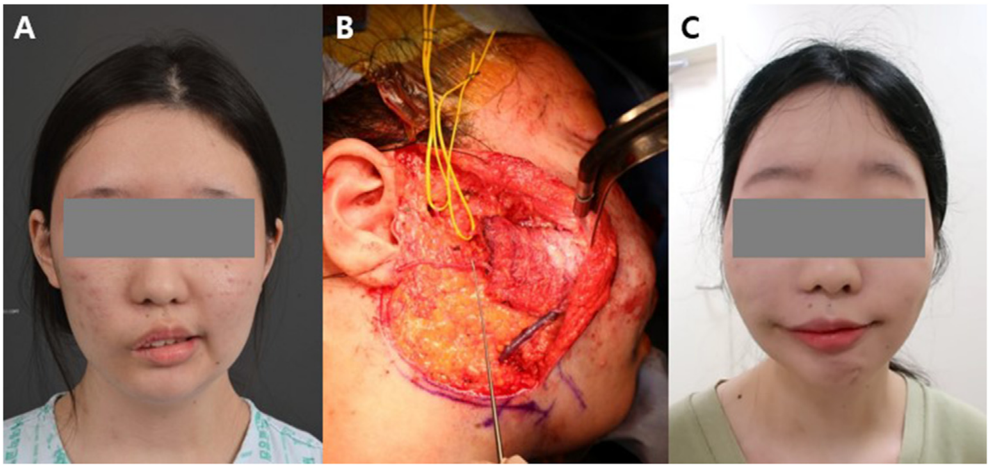

Fig. 5. A 21-year-old patient presented with complete right-sided facial paralysis after extirpation of pilocytic astrocytoma. After denervation time of 15 years, she underwent Partial LD transfer using single innervation method. (A) Preoperative photographic finding when smiling. (B) Intraoperative photographic finding after flap inset. (C) 1 year after reanimation surgery when smiling.

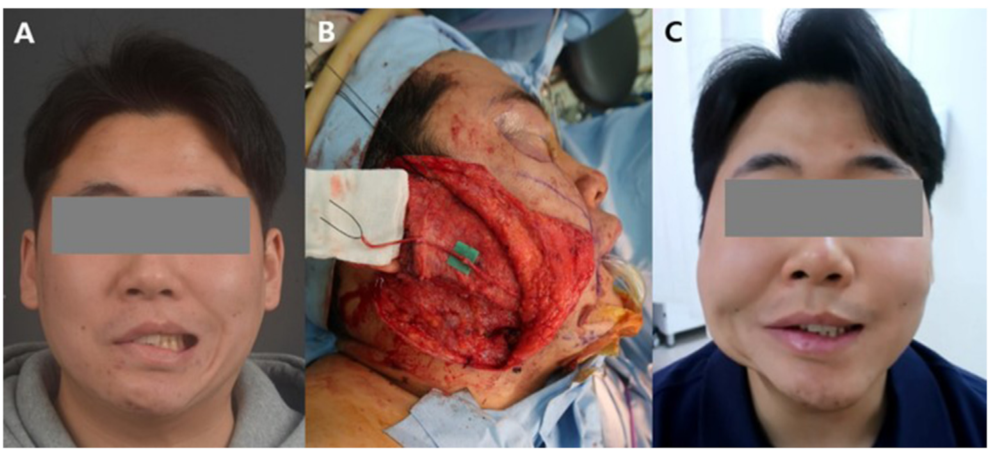

Fig. 6. A 20-year-old patient presented with complete right-sided facial paralysis after pedestrian traffic accident. After denervation time of 13 years, he underwent Partial LD transfer using dual innervation method. (A) Preoperative photographic finding when smiling. (B) Intraoperative photographic finding after flap inset. (C) 1 year after reanimation surgery when smiling.

Table 3
Outcome of Split LD transfer with nerve splitting method.

Surgical technique	Single innervation	Dual innervation	Value(p)
Number of voluntary smiles	7	9	
Number of spontaneous smiles	0	3	
No response after 1 year	1	1	
Analysis of smile outcomes			
Onset of voluntary smile, months	5.1	3.7	
Onset of spontaneous smile, months	None	10.3	
Smile excursion differences (+, mm)	5.8	6.0	0.88
Terzis grade differences (+)	2.5	2.8	0.35

branches of the TDN. Four patients who underwent this procedure showed a spontaneous smile after an average of 8 months. The authors suggested that the uncertainty of using double nerve innervation could be solved by combining two previously established methods. However, harvesting two separate muscle flaps can lead to longer operation times, and sacrificing the segment of the transverse branch of the TDN can be problematic when considering donor site functional morbidity.

Even though many surgeons have tried dual innervation methods, including the surgeons in our study, the theory involving one single muscle innervated by two separate motor nerves has still not been demonstrated. Although objective evaluation to identify which nerve is the main neurotizer could not be performed, we could observe that the dual innervation method has a positive effect on the generation of a spontaneous smile compared with the single innervation method. This can be explained by the neural supercharge concept, in which the masseteric nerve can augment neural signaling and the cross-facial nerve branch can offer spontaneity.

To explain how a spontaneous smile can be achieved using a single masseteric nerve as the motor source, which originates from the trigeminal nerve, the concept of cerebral adaptation should be discussed. Cerebral adaptation can be defined as the ability of the human brain to reorganize, adapt, and compensate for injury or change in the environment. In terms of facial reanimation, this can be explained by shifting control from the jaw muscle center to the facial movement center in the brain cortex (*Manktelow* et al., 2006).

Hontanilla et al. and Manktelow et al. (*Hontanilla and Cabello, 2016*; *Manktelow* et al., 2006) applied the concept of cerebral adaptation in facial reanimation. Manktelow et al. explained that if the facial nerve is disrupted, cortical pathways between the seventh and fifth nerve cortical centers can be activated. In simple terms, rehabilitation allows for the trigeminal nerve to take control of the dominant facial nerve. In this study, a spontaneous smile could be achieved in more than 88% of patients who underwent rehabilitation, even when the single innervation method using the masseteric nerve was adopted.

The single innervation method was adopted in patients who desired a less invasive procedure, with the expectation of a spontaneous smile by the theory of cerebral adaptation. However, we could not observe a spontaneous smile until 1 year postoperatively in the single innervation group. As all procedures were performed by the senior author (H.Chang) and the same rehabilitation protocol was carried out, patient factors, including compliance and individual differences in brain plasticity, may have influenced the outcomes. Other than patient factors, the patients were asked to smile with and without clenching their teeth for smile analysis. Additional assessments, such as recording of the patient when watching a funny video, could be more objective to determine whether the smile is spontaneous or not.

An interesting result was the earlier voluntary movement in the dual innervation group. It could be explained by the shorter neural pathway from the masseter motor nerve to the LD muscle segment. In the dual innervation method, the distal portion of the TDN, which coapted to the masseter nerve, was always shorter than the proximal portion of the TDN (6.7 cm vs. 11.3 cm), which was used in the single innervation method. A further study analyzing how the length of each TDN affects the onset of a voluntary/spontaneous smile may be valuable.

The effectiveness of TDN splitting was identified in a previous cadaver study performed in our department (*Kwon* et al., 2011). By performing interfascicular splitting of 42 latissimus dorsi muscles from 21 cadavers, preservation of remnant latissimus dorsi muscle function was possible, and its validity was confirmed by histology. With this novel nerve splitting method, a longer neurovascular pedicle could be obtained without the need for cross-face interpositional nerve grafting. In addition, the amount of work performed by the operator could be minimized, along with a decrease in axonal loss. Another advantage is low donor site morbidity by preserving the transverse branch of the TDN.

The dual innervation method utilizing the TDN can avoid atrophy of the transferred muscle by minimizing de-innervation time. The masseteric nerve can be used in a “baby-sitter” procedure until a spontaneous nerve source is obtained from the contralateral facial nerve branch. Additionally, masseteric nerve input can induce a voluntary smile, even if the neural source from the cross-facial nerve does not provide enough stimuli for a spontaneous smile. For instance, during unfavorable results, such as flap failure and insufficient neural recovery, it is a dilemma for surgeons to determine if they should try another new free flap or convert to static treatments, such as a tensor fascia latae or palmaris longus sling (*Park and Chang, 2019*; *Leckenby* et al., 2014; *Alexander* et al., 2011).

The masseteric nerve was selected as a motor input, as it is one of the most reliable motor nerve sources owing to its high axonal load and potential for cerebral adaptation, which can lead to a spontaneous smile (*Cassoni* et al., 2020; *Klebuc* and *Michael*, 2011). Compared with the hypoglossal nerve, which is another option for motor nerve input, the masseteric nerve shows faster onset of movement, greater symmetry, and absence of donor site morbidity (eg, injury related to tongue movement) (*Hontanilla and Marre, 2012*). The buccal branch (600–800 axons) of the facial nerve (the region between the first and second branches of the masseter nerve, which is approximately 2–3 cm from the origin of the nerve) was used for coaptation in our study owing to its high axonal load (*Goh* et al., 2016).

The study has several limitations that need to be mentioned. The conditions of the latissimus dorsi muscle, such as thickness and strength, can vary among patients. In addition, it was not possible to purely compare the two techniques, as the neural anastomosis method differed between the two groups (dual innervation method: proximal portion of the TDN to the contralateral buccal branch; single innervation method: proximal portion of the TDN to the ipsilateral masseteric nerve). However, the same recipient nerve and vessels were selected for more precise comparison. Furthermore, the follow-up period of 1 year could be regarded as short considering the duration of neural input crossover from the contralateral buccal branch of the facial nerve. A longer follow-up period may help obtain more precise outcomes. Lastly, objective evaluation to identify which nerve is the main neurotizer could not be performed. Recently, brain activation patterns were measured using effective protocols, such as functional magnetic resonance imaging (MRI) comparing the blood oxygen level-dependent signal during smiling and jaw clenching (*Romeo* et al., 2013; *Buendia* et al., 2016). If cortical plasticity is accurately mapped in future studies, functional MRI can be used as a valuable tool to understand the consequences and effectiveness of various facial reanimation procedures.

5. Conclusion

Within the limitations of the study it seems that partial LD transfer approach utilizing the dual innervation method has a positive effect on achieving a spontaneous smile and could be a valuable option for facial reanimation.

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Declaration of competing interest

The authors declare they have no competing interests.

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References

Alexander, A.J., de Almeida, J.R., Shrime, M.G., Goldstein, D.P., Gilbert, R.W., 2011. Novel outpatient approach to lower lip reanimation using a palmaris longus tendon sling. J. Otolaryngol. Head N 40 (6), 481–488.

Bae, Y.C., Zuker, R.M., Manktelow, R.T., Wade, S., 2006. A comparison of commissure excursion following gracilis muscle transplantation for facial paralysis using a cross-face nerve graft versus the motor nerve to the masseter nerve. Plast. Reconstr. Surg. 117 (7), 2407–2413.

Bianchi, B., Ferri, A., Poddi, V., Varazzani, A., Ferrari, S., Pedrazzi, G., et al., 2016. Facial reanimation with gracilis muscle transplant reinnervated via cross-face graft: does it change patient's quality of life? J. Cranio-Maxillo-Fac. Surg. 44, 934–939.

Biglioli, F., Colombo, V., Tarabbia, F., Autelitano, L., Rabbiosi, D., et al., 2012a. Recovery of emotional smiling function in free-flap facial reanimation. J. Oral Maxillofac. Surg. 70 (10), 2413–2418.

Biglioli, F., Colombo, V., Tarabbia, F., Pedrazzoli, M., Battista, V., et al., 2012b. Double innervation in free-flap surgery for long-standing facial paralysis. J. Plast. Reconstr. Aesthetic Surg. 65, 1343–1349.

Bray, D., Henstrom, D.K., Cheney, M.L., Hadlock, T.A., 2010. Assessing outcomes in facial reanimation: evaluation and validation of the SMILE system for measuring lip excursion during smiling. Arch. Facial Plast. Surg. 12, 352–354.

Buendia, J., Loayza, F.R., Luis, E.O., Celorrio, M., Pastor, M.A., Hontanilla, B., 2016. Functional and anatomical basis for brain plasticity in facial palsy rehabilitation using the masseteric nerve. J. Plast. Reconstr. Aesthetic Surg. 69, 417–426.

Cassoni, A., Catalano, C., Di Giorgio, D., Raponi, I., Di Brino, M., Perotti, S., Valentini, V., 2020. Masseter-facial neurorrhaphy for facial palsy reanimation: what happens after masseter denervation? Histomorphometric and stomatognathic functional analysis. J. Cranio-Maxillo-Fac. Surg. 48, 680–684.

Cardenas-Mejia, A., Covarrubias-Ramirez, J.V., Bello-Margolis, A., Rozen, S., 2015. Double innervated free functional muscle transfer for facial reanimation. J Plast Surg Hand Surg 49, 183–188.

Cuccia, G., Shelley, O., d'Alcontres, F.S., Soutar, D.S., Camilleri, I.G., 2005. A comparison of temporalis transfer and free latissimus dorsi transfer in lower facial reanimation following unilateral longstanding facial palsy. Ann. Plast. Surg. 54 (1), 66–70.

Dong, A., Zuo, K.J., Papadopoulos-Nydam, Georgina, Olson, J.L., Wilkes, G.H., Rieger, J., 2018. Functional outcomes assessment following free muscle transfer for dynamic reconstruction of facial paralysis: a literature review. J. Cranio-Maxillo-Fac. Surg. 46, 875–882.

Dusseldorp, J.R., van Veen, M.M., Guarin, D.L., Quatela, O., Jowett, N., Hadlock, T.A., 2019. Spontaneity assessment in dually innervated gracilis smile reanimation surgery. JAMA Facial Plast. Surg. 21 (6), 551–557.

Goh, T., Ang, C.H., Hwee, J., Bien-Keem, T., 2016. Defining the optimal segment for neurotization-Axonal mapping of masseter nerve for facial reanimation. Ann. Plast. Surg. 77, 450–455.

Guarin, D.L., Dusseldorp, J., Hadlock, T.A., et al., 2018. A machine learning approach for automated facial measurements in facial palsy. JAMA Facial Plast. Surg. 20, 335–337.

Guntinas-Lichius, O., Straesser, A., Streppel, M., 2007. Uality of life after facial nerve repair. Laryngoscope 117 (3), 421–426.

Harii, K., Asato, H., Yoshimura, K., Sugawara, Y., Nakatsuka, T., Ueda, K., 1998. One-stage transfer of the latissimus dorsi muscle for reanimation of a paralyzed face: a new alternative. Plast. Reconstr. Surg. 102, 941–951.

Hontanilla, B., Marre, D., 2012. Comparison of hemihypoglossal nerve versus masseteric nerve transpositions in the rehabilitation of short-term facial paralysis using the facial clima evaluating system. Plast. Reconstr. Surg. 130, 662e–672e.

Hontanilla, B., Cabello, A., 2016. Spontaneity of smile after facial paralysis rehabilitation when using a non-facial donor nerve. J. Cranio-Maxillo-Fac. Surg. 44, 1305–1309.

Iacolucci, C.M., Banks, C., Jowett, N., Kozin, E.D., Bhama, P.K., Barbara, M., Hadlock, T.A., 2015. Development and validation of a spontaneous smile Assay. JAMA Facial Plast. Surg. 17 (3), 191–196.

Klebuc, Michael JA., 2011. Facial reanimation using the masseter-to-facial nerve transfer. Plast. Reconstr. Surg. 127, 1909–1915.

Kwon, S.T., Chang, H., Oh, M., 2011. Anatomic basis of interfascicular nerve splitting of innervated partial latissimus dorsi muscle flap. J. Plast. Reconstr. Aesthetic Surg. 64, e109–e114.

Lassaletta, L., Alfonso, C., Del Rio, L., Roda, J.M., Gavilan, J., 2006. Impact of facial dysfunction on quality of life after vestibular schwannoma surgery. Ann. Otol. Rhinol. Laryngol. 115 (9), 694–698.

Leckenby, J.I., Harrison, D.H., Grobbelaar, A.O., 2014. Static support in the facial palsy patient: a case series of 51 patients using tensor fascia lata slings as the sole treatment for correcting the position of mouth. J. Plast. Reconstr. Aesthetic Surg. 67, 350–357.

Lifchez, S.D., Matloub, H.S., Gosain, A.K., 2005. Cortical adaptation to restoration of smiling after free muscle transfer innervated by the nerve to the masseter. Plast. Reconstr. Surg. 115, 1472–1479.

Manktelow, R.T., Tomat, L.R., Zuker, R.M., Chang, M., 2006. Smile reconstruction in adults with free muscle transfer innervated by the masseter motor nerve: effectiveness and cerebral adaptation. Plast. Reconstr. Surg. 118 (4), 885–899.

Nellis, J.C., Ishii, M., Byrne, P.J., Boahene, K.D., Dey, J.K., Ishii, L.E., 2017. Association among facial paralysis, depression, and quality of life in facial plastic surgery patients. JAMA Facial Plast. Surg. 19 (3), 190–196.

Okazaki, M., Kentaro, T., Noriko, U., Satoshi, U., Tsutomu, H., et al., 2015. One-stage dual latissimus dorsi muscle flap transfer with a pair of vascular anastomoses and double nerve suturing for long-standing facial paralysis. J. Plast. Reconstr. Aesthetic Surg. 68, e113–e119.

Park, J.H., Chang, H., 2019. Static treatment of incomplete facial paralysis with tensor fascia lata sling. J. Kor. Skull Base Soc. 14 (2), 39–43.

Romeo, M., Vizioli, L., Breukink, M., Aganloo, K., Lao, J., et al., 2013. A functional magnetic resonance imaging paradigm to identify distinct cortical areas of facial function: a reliable localizer. Plast. Recontr. Surg. 131, 527e–533e.

Sforza, C., Frigerio, A., Mapelli, A., Tarabbia, F., Annoni, I., et al., 2015. Double-powered free gracilis muscle transfer for smile reanimation: a longitudinal optoelectronic study. J. Plast. Reconstr. Aesthetic Surg. 68, 930–939.

Terzis, J.K., Noah, M.E., 1997. Analysis of 100 cases of free-muscle transplantation for facial paralysis. Plast. Reconstr. Surg. 99, 1905–1921.