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Dual Coaptation of Facial Nerve Using Masseteric Branch of Trigeminal Nerve for Iatrogenic Facial Palsy: Preliminary Reports

Yoon Se Lee, MD, PhD[1], Joong Ho Ahn, MD, PhD[1], Hong Ju Park, MD, PhD[1], Ho Jun Lee, MD[1], Mi Rye Bae, MD[1], Jong-Lyel Roh, MD, PhD[1], Seung-Ho Choi, MD, PhD[1], Soon Yuhl Nam, MD, PhD[1], and Sang Yoon Kim, MD, PhD[1]

Abstract

Objectives: Immediate facial nerve substitution or graft technique has been used for the repair of facial nerve defects occurring as a result of tumour dissection. However, some patients report unsatisfactory outcomes, such as difficulty in maintaining resting or smiling symmetry, due to persistent flaccid facial palsy. Here we evaluated the functional outcomes of transferring the masseteric branch of the trigeminal nerve to the facial nerve adjunct to facial nerve graft.

Methods: We reviewed the medical records of seven patients who underwent facial reanimation surgery between 2014 and 2016. The patients were divided into two groups according to the type of facial reanimation surgery: group A, masseteric nerve innervation with interposition graft; group B, interposition graft only. The postoperative resting symmetry and dynamic movement were compared.

Results: Facial contraction was first observed in group A at 4 months and in group B at 7.3 months. Most of the patients achieved reliable resting symmetry; however, one patient in group B exhibited unsatisfactory facial weakness on the affected side. Group A patients showed better dynamic movement than group B patients. Eye closure, oral excursion and oral continence were better in group A than in group B patients. Smile symmetry in both groups was similar due to hyperkinetic movement in group A patients and flaccidity in group B patients.

Conclusions: Dual innervation of the masseteric branch of the trigeminal nerve improves the dynamic movement of paralysed facial muscles and shortens the recovery period in patients with iatrogenic facial palsy.

Keywords

facial palsy, facial nerve, masseteric nerve, graft, anastomosis, greater auricular nerve

Introduction

Resection of tumours arising from or invading the facial nerve is the most common cause of iatrogenic facial palsy.[1] In cases with facial nerve involvement by a parotid cancer, the nerve should be transected to secure a safe margin, which induces complete facial palsy.[2] In cases with skull base lesions, such as acoustic neuroma and cholesteatoma, facial nerve continuity is usually preserved, although this does not guarantee the preservation of facial nerve function. Facial palsy is a devastating condition with profound functional, aesthetic and psychosocial implications. Thus, in addition to tumour eradication, adequate management of facial asymmetry is advocated to maintain the social interaction and quality of life of patients.[3] Facial nerve decompression is indicated when the continuity of the nerve is preserved, whereas facial reanimation surgery is indicated when complete facial palsy with a low possibility of recovery is suggested by electrophysiological test results or pathological background. The duration of facial palsy, amount of available proximal facial nerve stump and activity of the facial muscles are the major determining factors when selecting the surgical treatment.[4]

In cases of complete facial palsy due to mass invasion, either facial nerve coaptation using interposition graft or muscle transposition is necessary. When proximal facial stump function is available, nerve graft is applied to connect

[1]Department of Otolaryngology, Asan Medical Centre, College of Medicine, University of Ulsan, Seoul, Korea

Corresponding Author:
Yoon Se Lee, MD, PhD, Department of Otolaryngology, Asan Medical Center, 88, Olympic-ro 43-gil, Songpa-gu, Seoul 05505, Republic of Korea.
Email: yselee@amc.seoul.kr

Table 1. Demographic Findings.

Patient Number	Gender	Age	Cause	Type of Facial Reanimation Surgery
1	Male	59	Parotid cancer	Trigeminal innervation into GAN graft
2	Male	46	Parotid cancer	Trigeminal innervation into GAN graft
3	Male	16	Acoustic schwannoma	Trigeminal innervation into facial nerve
4	Male	24	Cholesteatoma	Trigeminal innervation into facial nerve
5	Female	51	Acoustic schwannoma	GAN interposition
6	Male	68	Parotid cancer	GAN interposition
7	Female	53	Parotid cancer	GAN interposition

Abbreviation: GAN, greater auricular nerve.

the proximal facial nerve to the viable distal facial nerve. Based on this concept, heterogeneous surgical management of the paralysed face has been applied to achieve the best treatment outcomes.[5] Alternate motor sources include the hypoglossal nerve, contralateral facial nerve and masseteric branch of the trigeminal nerve. The gap between the motor source and the distal facial nerve is connected using nerve grafts. The preferred nerves for graft harvesting include the greater auricular nerve (GAN) and sural nerve. The greater auricular nerve is generally used because of proximity to the facial nerve during mastoid or parotid surgery.[6] After reinnervation with these interposition nerve grafts, a substantial number of patients reportedly presented with unsatisfactory outcomes; insufficient neuronal recruit or technical problems of neural coaptation have been found to be responsible for persistent weakness and additional innervation (neural supercharge), which is believed to result in a high muscle fibre impulse.[7] Augmenting the neural stimuli to distal nerves may increase the possibility of neuronal and muscular regeneration, leading to optimal facial results.

In 1978, Spira first described the transfer of motor branch of the masseteric branch of the trigeminal nerve for the reinnervation of free muscle transfers in facial reanimation.[8] The low morbidity, adjacent location of the masseteric nerve to the facial nerve and strong neural impulse all result in reliable surgical outcomes. Masseteric branch is applied for the direct neurotisation of the facial nerve branches and babysitter procedures in the setting of cross-face nerve grafting (CFNG).[9-11] Although the masseteric branch is used to temporarily maintain the muscle tone before successful neural sprouting from CFNG, the masseteric branch is not usually dissected after the completion of CFNG. Different from this dual innervation process, double innervation with the masseteric branch coaptation of the facial nerve branch in association with CFNG has also been considered.[12] Despite the versatile role of the masseteric nerve in reinnervation, reports on ipsilateral facial stimuli combined with masseteric innervation are rare.

Combined neural stimuli from the masseteric branch with the proximal facial nerve via interposition graft may help improve facial functions. This study was designed to evaluate the facial expression outcomes after facial nerve interposition graft with or without masseteric branch anastomosis.

Patients and Methods

We reviewed the medical records of patients with facial palsy caused by intratemporal or extratemporal mass between January 2014 and December 2016. Among them, the patients who had the facial nerve defect occurred during mass resection were included. The presence of the proximal facial nerve was confirmed before and during surgery. The patients received facial reanimation surgery using nerve interposition technique with or without masseteric nerve innervation. Seven patients (five men and two women) with complete facial palsy were enrolled in this study (Table 1). The patients were divided into two groups according to the neural graft methods used: group A, facial nerve interposition graft with masseteric nerve innervation; group B, facial nerve interposition graft only. Patients #1 and #2 received interposition graft between the facial nerve trunk and the distal branches of the facial nerve and additional masseteric innervation to the graft end to side manner (Figure 1A). Patients #3 and #4 received masseteric innervation at the intact extratemporal facial nerve trunk after interposition graft in the intratemporal portion of the facial nerve (Figure 1B). Patient #3 was referred from another hospital after facial nerve interposition graft between the 1st genu and the mastoid portion of the facial nerve. Group B patients received an interposition graft between the facial nerve and the distal trunk (patient #5) or distal branch of the facial nerve (patients #6 and #7). Patients with $<$18 years old, a history of masseteric nerve injury, dysphagia or prolonged facial palsy for $>$24 months were excluded from this study. This study was approved by the Institutional Review Board.

Procedure

A modified Blair incision or a large C-shaped incision was made on the affected side, and parotidectomy for mass resection was performed in an anterograde manner following the

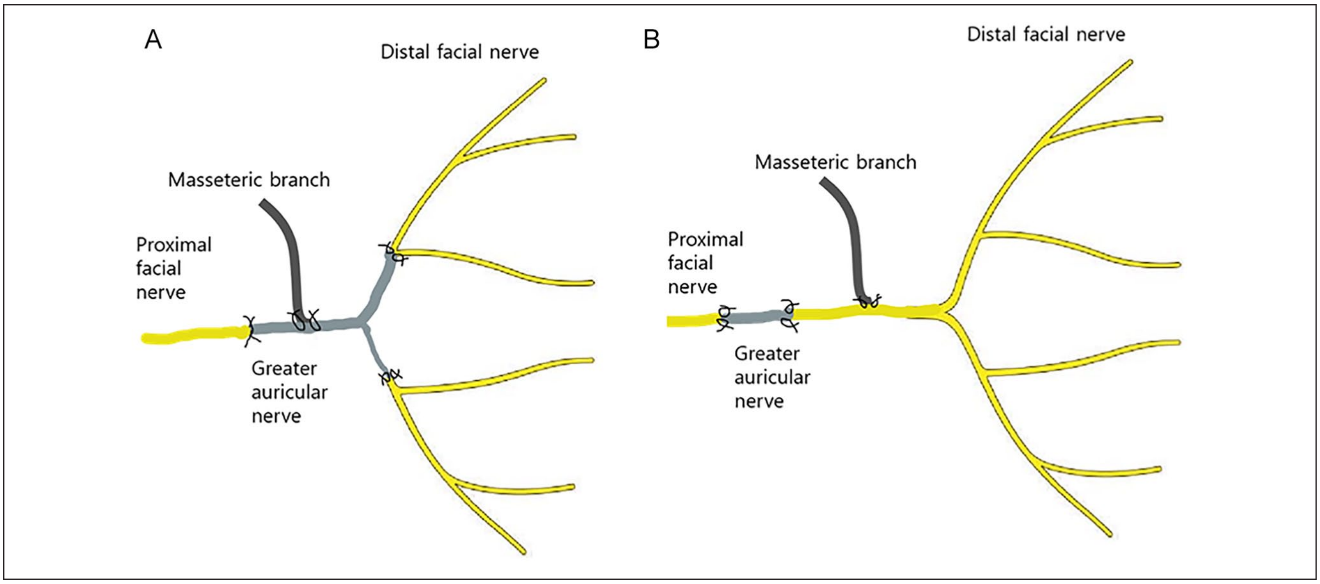

Figure 1. Two types of dual innervations of the masseteric and facial nerve interposition graft. The masseteric nerve was sutured to the interposition graft between the proximal stump of the facial nerve and the distal facial nerve trunk (A) or the distal branch of the extratemporal facial nerves (B).

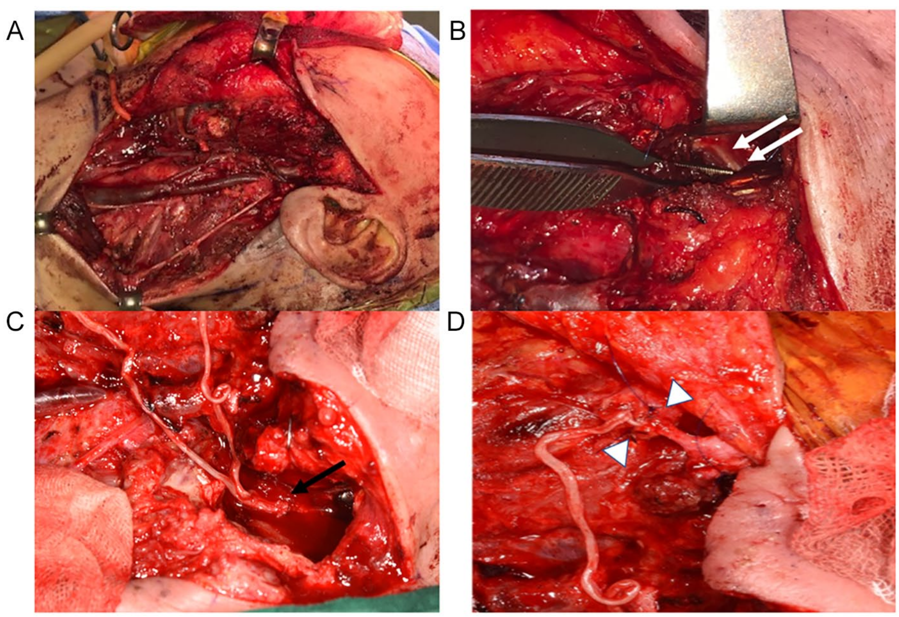

Figure 2. Surgical findings for left salivary ductal cell carcinoma causing complete facial palsy. (A) Left radical parotidectomy with modified radical neck dissection. (B) Identification of the masseteric branch (white arrow). (C) Anastomosis between the greater auricular nerve graft and the proximal stump of the facial nerve (black arrow). (D) Anastomosis between the masseteric branch and the greater auricular nerve graft.

identification of the facial nerve trunk at the stylomastoid foramen (Figure 2A). In cases of acoustic schwannoma and cholesteatoma, the involved facial nerve was resected with the tumour after mastoidectomy and parotidectomy to visualize both the proximal and the distal facial nerve ends. Because the main purpose of the surgery was to remove the tumour that was invading the facial nerve in cases of parotid cancer, the parotid gland was partially or completely removed to secure complete lesion removal. Distal extratemporal branches, including the temporal, zygomatic,

Table 2. Postoperative Outcomes.

			Dynamic Symmetry			
Patient Number	Group	Resting Symmetry	Eye Closure	Oral Excursion	Oral Continence	Smile
1	A	4	4	4	5	3
2	A	5	4	4	3	4
3	A	5	4	4	4	4
4	A	5	4	5	5	4
5	B	4	3	3	4	3
6	B	3	2	4	2	3
7	B	5	3	4	4	3

Note. 1; poor, 2; fair, 3; moderate, 4; good, 5; excellent.

buccal, marginal and cervical branches, were identified. The masseteric motor branch of the trigeminal nerve was detected by dissecting through the subzygomatic triangle, which comprises the zygomatic arch, temporomandibular joint and frontal branch of the facial nerve (Figure 2B).[13] A nerve stimulator was used to confirm the motor branch that contracts the masseter muscle. The masseteric branch of the trigeminal nerve was exposed via anterograde dissection to obtain sufficient length of the proximal stump of the masseteric branch and to reduce the tension between the proximal and distal stumps.

GAN was harvested, and a small segment of the nerve close to the parotid gland was dispatched for frozen biopsy to confirm the absence of perineural invasion in parotid cancer. When harvesting GAN, the collateral branch from the main branch of GAN was preserved as much as possible. This procedure allows anastomosis between the multiple distal branches of the facial nerve and GAN without dividing the end of GAN. After manipulating the nerve graft and facial nerve proximal stumps ends using a scalpel, proximal coaptation between the facial nerve trunk and the distal end of GAN and distal coaptation between the distal facial nerve branches and the proximal end of GAN by dividing its ends were performed by placing a few epineural 9-0 or 10-0 sutures (Figure 2C). After placing the interposition graft, the distal end of the masseteric branch was sectioned and coaptated with the facial nerve or GAN, where a few epineural 9-0 or 10-0 sutures were placed (Figure 2D).

Evaluation

The parameters determining facial nerve functions included resting symmetry and dynamic symmetry upon eye closure, oral excursion, oral incontinence, smiling and synkinesis. The Terzis scale was used to evaluate the results.[9] Facial movement was usually evaluated every 3 months after the surgery. More frequent surveillance for the possibility of recurrence was required for parotid cancer patients during the first year after surgery. The surgical results were evaluated for at least 12 months.

Results

The recovery of facial mimetic contraction began within 6 months in group A (mean: 4 months, range: 2–5 months), whereas it was delayed by >6 months in group B (mean: 7.3, range: 6–8 months).

Both group A and B patients showed more than fair resting symmetry. Patient #6 showed flaccid facial movement, which causes discrete facial asymmetry. Group A patients showed better dynamic symmetry than group B patients (Table 2). Figure 3 depicts the representative results of combined masseteric innervation with the interposition graft after radical parotidectomy for salivary ductal cell carcinoma. The affected eye in group A was closed with minimal to moderate effort. Group B patients needed moderate to maximum effort to close the affected eye. Patient #6 with incomplete eye closure and recurrent keratitis underwent additional platinum insertion into the upper eyebrow to achieve eye closure. Oral excursion and oral continence while sipping water or chewing were improved and acceptable in group A patients. No patient complained of drooling in the resting state, except for patient #6, who presented with decreased muscle tone. However, increased buccal muscle tone helped patients during mastication without biting or affecting the buccal mucosa. Later, patient #6 received static suspension to maintain the resting symmetry of midface. Smiling symmetry was not completely achieved, generally because of hyperkinetic movement in group A and flaccid movement in group B.

No complication requiring immediate surgical intervention was noted (Table 3). Synkinesis after dual innervation was the main complication associated with this dual coaptation method. All group A patients demonstrated oral–ocular synkinesis on masticating or chewing (Figure 4). Most patients did not complain of synkinesis, except one; longer follow-up is necessary when expecting cortical plasticity to coordinate masticatory and facial movements, such as spontaneous smile. Complaining prominent synkinesis can be corrected using botulinum toxin injections or via masseteric nerve resection. Patient #4 complained of severe synkinesis that was not controlled for 5 months after the onset. He

Figure 3. Results of left dual innervation by the masseteric nerve and interposition graft after 8-month follow-up. (photograph published with the permission of this patient).

Table 3. Complications after Facial Reanimation Surgery According to the Type of Innervation.

	Number of Patients (%)	
Complications	Group A	Group B
Trismus	1 (25%)	0
Synkinesis	4 (100%)	2 (66.7%)
Bleeding	0	0
Sialocele or seroma	2 (50%)	1 (33.3%)
Wound infection	0	0
Additional surgery	2 (50%)	2 (66.7%)

received botulinum toxin injection around the lateral portion of his orbicularis oculi muscle, which resulted in only a transient effect on synkinesis. He underwent dissection of the masseteric branch at the neurorrhaphy site. The other three patients adjusted themselves to synkinesis between the eyebrow movement and mastication. In group B, synkinesis (oculo–oral, oral–ocular or mixed type) was noted in two patients who showed better facial movement than the remaining one patient. Synkinesis in group B patients was not very evident, and no additional treatment was performed for the same. In group A, none of the patients suffered from masticatory dysfunction due to the denervation of the masseter muscle. One patient experienced transient trismus after the surgery, which was relieved after 2 months. Sialocele was detected in both the groups, and it was relieved after repeated aspiration and compression. Additional treatments included platinum insertion into the eyebrow (patients #1 and #6), dissection of anastomosis (patient #4) and static surgery of the midface (patient #6).

Discussion

Facial expression involves the coordination or discrete motions of the facial mimetic muscles. Facial static or dynamic asymmetry after iatrogenic facial injury is difficult to re-establish despite the development of various surgical techniques for the same. One of the key factors in facial neurotisation procedures is obtaining sufficient motor source to stimulate the distal facial nerve and muscles. If the facial nerve is removed along with the tumour, the facial nerve must be reconstructed for continuity to maintain neural stimuli to the distal muscles; this is usually achieved by using the interposition graft.[14] Single innervation in this study resulted in variable muscle activity, which often comprises hypotonic movements. Dual innervation was used to compensate for the decreased motor stimuli to the distal facial nerve. Identifying patients who will benefit from additional innervation is thus necessary, but no reliable predicting factors have yet been elucidated.[15] This study aimed to reveal the surgical feasibility and benefits of additional neural stimulus derived from the masseteric nerve. The masseteric and hypoglossal nerves can act as alternate motor sources that can be easily accessed in the mastoid or parotid surgical field. This preliminary study revealed that additional innervation provided by the masseteric branch to the facial interposition graft improved the dynamic facial mimetic movement rather than the flaccid facial movement. Furthermore, the results suggest that dual innervation by the ipsilateral facial nerve (or graft) and masseteric branch leads to rapid recovery and more dynamic movement compared with a single facial nerve coaptation. However, fine tuning of the hyperkinetic facial mimetic movement is still necessary.

The motor nerve to the masseter muscle (ie, the masseteric branch) originates from the anterior division of the mandibular branch of the trigeminal nerve and is the largest of the three motor branches of the trigeminal nerve.[16] The masseteric branches in facial reanimation act as a reliable motor source and are used in three procedures: direct motor neurotisation, babysitter procedure and innervation for neuromuscular transplants.[17] Previously, dual innervation of the contralateral facial nerve and masseteric branch as part of free muscle transfer have also been reported.[18] The trigeminal nerve offers benefits as an alternate or additional motor source for the facial nerve compared with the hypoglossal nerve. The hypoglossal nerve may cause tongue atrophy, and the quantity of motor fibres from the hypoglossal nerve is likely to be inconsistent. The proximity of the masseteric

Figure 4. Oral–ocular synkinesis after right dual innervation by the masseteric nerve and interposition graft at 12-month follow-up. (photograph published with the permission of this patient).

branch to the facial nerve and similar diameters of these nerves facilitate direct anastomosis without interposition graft.[19] The coaptation of the masseteric branch to the temporofacial branch is easy due to their proximity. After radical or total parotidectomy, further incision is not required to detect the masseteric branch. Moreover, radical approach to the skull base, such as via the infratemporal fossa approach, provides easy accessibility to the masseteric branch. Facial nerve rerouting after mastoidectomy and graft elongation may secure additional length in order to facilitate neurotisation between the facial nerve and the masseteric nerve. The adjacent location of the trigeminal and facial nuclei and nerves is related to the ease of cerebral adaptation after the masseteric to facial nerve transfer.[20] Furthermore, consistent results for reanimation of long-standing facial palsy with gracilis muscle transplants innervated by the masseteric branch have been reported.[21] This led to the idea that masseteric nerve innervation to the facial nerve would produce natural smiling without affecting masticator functions. We believe that the facial nerve and masseteric branch are responsible for spontaneous facial movements and adjuvant motor input, respectively. Considering that group A patients showed hyperkinetic movement, motor stimuli was sufficient in them to activate the facial mimetic movement more compared with that in group B patients. However, synkinesis was observed in all group A patients, and coordination via the intact facial nerve stimulus was not successfully achieved. The overriding input of the trigeminal nerve is believed be one of the reasons. After the reanimation, cortical plasticity is expected for cortical adaptation and spontaneous activation of the trigeminal nuclei.[22] Viable facial muscle is a prerequisite for neurotisation.[23] Atrophic changes in the facial muscles were not evident on preoperative magnetic resonance or computed tomography images, which were used to evaluate the extent of tumour. The denervation period of the enrolled patients did not exceed 24 months, which assumes the viability of the facial muscles.

It usually takes approximately 3 months to notice the first clinical facial movement after facial reanimation surgery.[24] This study showed that early facial contraction was observed within 2 months in group A patients. Group A patients showed faster and stronger facial movements than group B patients. Dual innervation, rather than single innervation, may potentiate the neuronal stimuli that initiate facial movements. The disadvantages of the masseteric nerve transfer include slight weakness during mastication and masseteric atrophy. The functional loss of masseter muscles is believed to be compensated by other masticatory muscles, such as the temporalis, pterygoid and contralateral masseter muscles.[25] The patients enrolled in this study did not present with permanent masticatory weakness. Because of the surgical defect after parotidectomy, the role of masseteric atrophy in facial asymmetry was not prominent. The patients with parotid cancer planned to receive adjuvant radiation therapy, which delayed the additional flap reconstruction planned for camouflaging the surgical defects. No evidence of recurrence is expected to be confirmed before another surgical intervention after at least 2 years. Further improvement can be expected after radiation therapy, which is reported to not affect the reconstructed facial function.[26]

This study has some limitations. First, the number of enrolled patients in this study was insufficient to validate the significance of the results. However, the study results suggest the feasibility of additional coaptation of the trigeminal nerve to the facial nerve. The neurotisation of the masseteric nerve to the graft or the facial trunk may have presented with different surgical outcomes. In this study, no significant difference was noted between the results obtained with the two neurotisation methods. After dual innervation, group A showed better functional improvement in eye closure and oral competence. The management of cosmetic impairment should be approached from multiple aspects, including surgical defect, volume change after radiation therapy, skin colour and scarring. Dual innervation using the masseteric nerve provides sufficient motor stimuli to recover the facial muscular activity, which will contribute to resolve the cosmetic impairment in patients with facial palsy.

Conclusion

The addition of the masseteric nerve to the interposition graft generates motor stimuli to improve facial functions. Dual innervation using the masseteric nerve offers an advantage of dynamic facial motion in addition to static symmetry. However, fine tuning of the hyperkinetic movement following dual innervation is necessary. Reliable outcomes and low complication rate are the benefits of dual innervation with the masseteric nerve.

Declaration of conflicting interests

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ORCID iDs

Yoon Se Lee https://orcid.org/0000-0001-6534-5753
Hong Ju Park https://orcid.org/0000-0002-6331-8556
Jong-Lyel Roh https://orcid.org/0000-0002-1537-1977

References

1. Hohman MH, Hadlock TA. Etiology, diagnosis, and management of facial palsy: 2000 patients at a facial nerve center. *Laryngoscope*. 2014;124(7):E283-E293.
2. Guntinas-Lichius O, Silver CE, Thielker J, et al. Management of the facial nerve in parotid cancer: preservation or resection and reconstruction. *Eur Arch Otorhinolaryngol*. 2018;275(11): 2615-2626.
3. Ishii L, Godoy A, Encarnacion CO, et al. Not just another face in the crowd: society's perceptions of facial paralysis. *Laryngoscope*. 2012;122(3):533-538.
4. Jowett N, Hadlock TA. A contemporary approach to facial reanimation. *JAMA Facial Plast Surg*. 2015;17(4):293-300.
5. Kim L, Byrne PJ. Controversies in contemporary facial reanimation. *Facial Plast Surg Clin North Am*. 2016;24(3):275-297.
6. Lombardi D, McGurk M, Vander Poorten V, et al. Surgical treatment of salivary malignant tumors. *Oral Oncol*. 2017;65: 102-113.
7. Yamamoto Y, Sekido M, Furukawa H, et al. Surgical rehabilitation of reversible facial palsy: facial–hypoglossal network system based on neural signal augmentation/neural supercharge concept. *J Plast Reconstr Aesthet Surg*. 2007;60(3):223-231.
8. Spira M. Anastomosis of masseteric nerve to lower division of facial nerve for correction of lower facial paralysis. Preliminary report. *Plast Reconstr Surg*. 1978;61(3):330-334.
9. Terzis JK, Noah ME. Analysis of 100 cases of free-muscle transplantation for facial paralysis. *Plast Reconstr Surg*. 1997; 99(7):1905-1921.
10. Terzis JK, Tzafetta K. The "babysitter" procedure: minihypoglossal to facial nerve transfer and cross-facial nerve grafting. *Plast Reconstr Surg*. 2009;123(3):865-876.
11. Hontanilla B, Marre D, Cabello A. Masseteric nerve for reanimation of the smile in short-term facial paralysis. *Br J Oral Maxillofac Surg*. 2014;52(2):118-123.
12. Bianchi B, Ferri A, Ferrari S, et al. The masseteric nerve: a versatile power source in facial animation techniques. *Br J Oral Maxillofac Surg*. 2014;52(3):264-269.
13. Dauwe PB, Hembd A, De La Concha-Blankenagel E, et al. The deep temporal nerve transfer: an anatomical feasibility study and implications for upper facial reanimation. *Plast Reconstr Surg*. 2016;138(3):498e-505e.
14. Vaughan E, Richardson D. Facial nerve reconstruction following ablative parotid surgery. *Br J Oral Maxillofac Surg*. 1993;31(5):274-280.
15. Boahene K. Facial reanimation after acoustic neuroma resection: options and timing of intervention. *Facial Plast Surg*. 2015;31(2):103-109.
16. Fournier HD, Denis F, Papon X, et al. An anatomical study of the motor distribution of the mandibular nerve for a masseteric-facial anastomosis to restore facial function. *Surg Radiol Anat*. 1997;19(4):241-244.
17. Henstrom DK. Masseteric nerve use in facial reanimation. *Curr Opin Otolaryngol Head Neck Surg*. 2014;22(4):284-290.
18. Hontanilla B, Marre D, Cabello A. Facial reanimation with gracilis muscle transfer neurotized to cross-facial nerve graft versus masseteric nerve: a comparative study using the FACIAL CLIMA evaluating system. *Plast Reconstr Surg*. 2013;131(6):1241-1252.
19. Cotrufo S, Hart A, Payne AP, et al. Topographic anatomy of the nerve to masseter: an anatomical and clinical study. *J Plast Reconstr Aesthet Surg*. 2011;64(11):1424-1429.
20. Lifchez SD, Matloub HS, Gosain AK. Cortical adaptation to restoration of smiling after free muscle transfer innervated by the nerve to the masseter. *Plast Reconstr Surg*. 2005;115(6):1472-1479; discussion 1480-1472.
21. Bae YC, Zuker RM, Manktelow RT, et al. 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*. 2006;117(7):2407-2413.
22. Manktelow RT, Tomat LR, Zuker RM, et al. Smile reconstruction in adults with free muscle transfer innervated by the masseter motor nerve: effectiveness and cerebral adaptation. *Plast Reconst Surg*. 2006;118(4):885-899.
23. Fattah A, Borschel GH, Manktelow RT, et al. Facial palsy and reconstruction. *Plast Reconst Surg*. 2012;129(2):340e-352e.
24. Guntinas-Lichius O, Streppel M, Stennert E. Postoperative functional evaluation of different reanimation techniques for facial nerve repair. *Am J Surg*. 2006;191(1):61-67.
25. Grunheid T, Langenbach GE, Korfage JA, et al. The adaptive response of jaw muscles to varying functional demands. *Eur J Orthod*. 2009;31(6):596-612.
26. Hontanilla B, Qiu SS, Marre D. Effect of postoperative brachytherapy and external beam radiotherapy on functional outcomes of immediate facial nerve repair after radical parotidectomy. *Head Neck*. 2014;36(1):113-119.