Acta Neurochirurgica (2019) 161:1089–1094
https://doi.org/10.1007/s00701-019-03901-9

CASE REPORT - PERIPHERAL NERVES

Masseteric nerve supercharge bypass in primary reconstruction of facial nerve

Petr Vachata[1,2] · Stepanka Brusakova[3] · Jan Lodin[1] · Martin Sames[1]

Received: 1 February 2019 / Accepted: 28 March 2019 / Published online: 13 April 2019

Abstract
Facial paralysis is a severe disease and presents a formidable treatment challenge. A wide variety of surgical procedures are available with limited evidence. Major risk factors of suboptimal recovery include the duration of paralysis as well as higher age. In this paper, we demonstrate reconstruction of the facial nerve via an intratemporal end-to-end anastomosis and concomitant transfer of an intact masseteric nerve to the side of facial nerve trunk. The supercharge (reverse end-to-side) transfer resulted in preservation of target muscles and faster recovery. Masseteric supercharge bypass may be an acceptable surgical technique to restore muscle function in potentially higher risk cases.

Keywords Facial nerve palsy · Masseteric nerve · Nerve transfer · Supercharge bypass

Introduction

Facial nerve paralysis is a condition resulting in serious functional, cosmetic, and psychological problems. Optimal reconstruction techniques of the facial nerve, resulting in improved function, remain a challenge and there is currently no consensus on ideal therapeutic management of these patients. Adequate treatment depends on many factors such as type of palsy, time elapsed since injury, prognosis, age, and general health of the patient. Of these factors, time of denervation and patient age are the most important [12, 14, 25, 33]. In cases of acute intraoperative lesions with short-term paralysis lasting up to 12 months and an available proximal nerve stump, a direct facial nerve reconstruction is the best option. In cases of denervation exceeding 2 years, a muscle transplant is necessary due to irreversible atrophy of the mimic musculature. Lesions between 12 and 24 months treated by isolated facial nerve repair are at risk of suboptimal functional recovery; therefore, muscle transfers are reasonable options, preferred by many reconstructive surgeons [30]. In this paper, we report a case of complete intratemporal facial nerve injury treated via an intratemporal nerve reconstruction and a concomitant masseteric nerve reverse end-to-side transfer.

Clinical presentation

A 68-year-old male was referred to our center with persisting complete facial nerve paralysis on the left side. Fourteen months before to this, the patient had a traffic accident with a brain contusion and skull base fractures including a comminuted fracture of the left pyramid (Fig. 1).

Preoperative clinical evaluation and electrodiagnostic tests

Patient presented with complete unilateral facial nerve palsy on the left side with the absence of clinical movement and no signs of recovery on needle electromyography. The ipsilateral masseteric nerve function and electromyography were without deterioration. Pure tone audiometry confirmed complete loss of hearing on the ipsilateral side. The patient did not complain of tearing problems. After a thorough consultation with the patient, a surgical course of treatment was chosen.

This article is part of the Topical Collection on *Peripheral Nerves*

✉ Petr Vachata
vachata@gmail.com

[1] Department of Neurosurgery, Masaryk Hospital, J. E, Purkyně University, Socialni pece 3316/12A, 40113 Usti nad Labem, Czech Republic

[2] Department of Neurosurgery, Faculty of Medicine in Pilsen, Charles University, Alej Svobody 80, 30100 Pilsen, Czech Republic

[3] Department of Neurology, Masaryk Hospital, Socialni pece 3316/12A, 40113 Usti nad Labem, Czech Republic

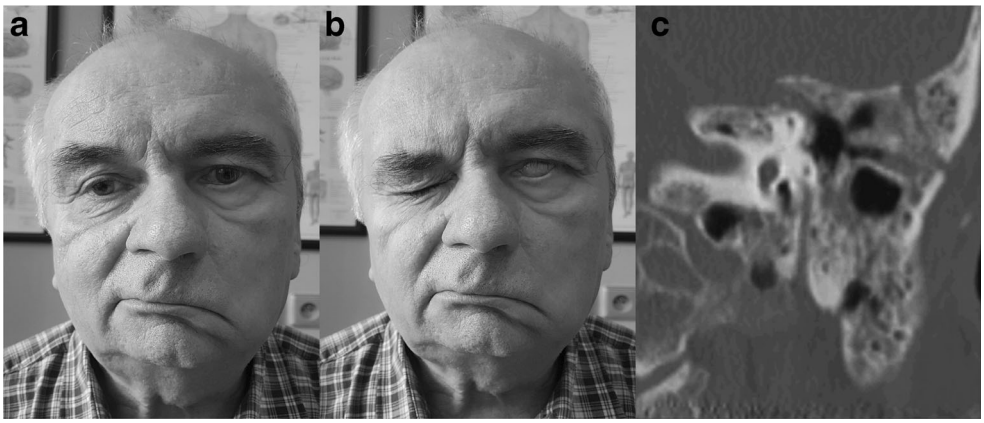

Fig. 1 Preoperative complete facial nerve paralysis on the left side (**a**, **b**) and comminuted temporal bone fracture (**c**)

The surgical plan was intratemporal reconstruction of the damaged facial nerve and a simultaneous masseteric nerve supercharge transfer to the facial nerve trunk to improve reinnervation of the mimic muscles. Ethical approval was obtained.

Surgical technique

The radical mastoid approach was used to reveal the entirety of the facial nerve canal. Two facial nerve defects were identified in close proximity to the geniculate ganglion. The nerve was rerouted from the bony canal and a tension-free end-to-end anastomosis was performed. A sural graft was harvested simultaneously. A 4-cm preauricular incision was made anterior to the tragus in order to dissect the facial nerve trunk and the masseteric nerve. The location of masseteric nerve is typically a constant, located at a point 4 cm anterior to the tragus, 1 cm below the zygomatic arch and 1.5 cm deep in the area of the mandibular notch under a layer of masseteric muscle fibers. Following verification via electrostimulation, the nerve was transected preserving maximum length and rotated toward the facial nerve trunk. The masseteric stump was adapted to the sural nerve graft in an end-to-end technique with a 10/0 epineural suture under a microscope control. The second end of the sural graft was subsequently adapted to the facial nerve trunk via an end-to-side technique using 10/0 epineural sutures through a perineurial window (Fig. 2).

Follow-up and surgical outcome

The postoperative course was uneventful and the patient underwent postoperative physiotherapy. The patient was regularly clinically and electromyographically evaluated throughout a 3-month postoperative period. The first control showed no signs of reinnervation. The recovery time of muscle tone with improvement of oral competence, without

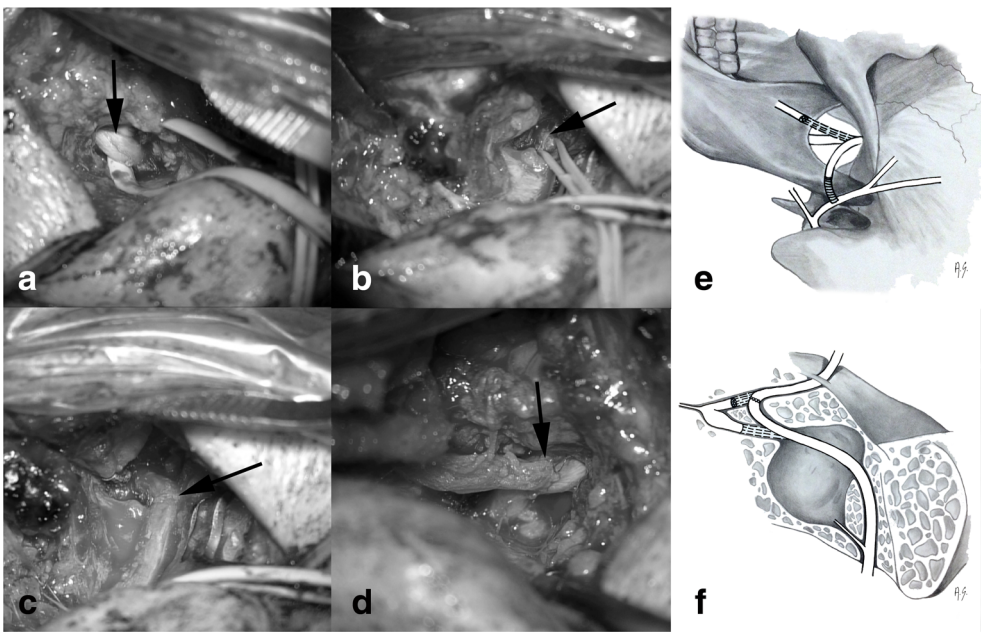

Fig. 2 Intraoperative identification of the facial nerve trunk (**a**, arrow) and masseteric nerve (**b**, arrow). Subsequent coaptation of the masseteric nerve to the sural nerve graft in an end-to-end technique (**c**, arrow) and coaptation of the graft to the facial nerve trunk via an end-to-side technique (**d**, arrow). Corresponding scheme of masseteric supercharge bypass with interposition of sural nerve graft between the rotated masseteric nerve and facial nerve trunk (**e**). Scheme of intratemporal rerouting of the tympanic and labyrinthine part of the facial nerve (**f**)

drooling or spillage of food and drink, was 6 months. Simultaneously, initial facial nerve movement was observed in the malar region along with jaw clench. The electrophysiological evaluation confirmed reinnervation in muscles of both branches, with richer and more mature voluntary activity in the orbicularis oris muscle. Three months later, palpebral closing significantly improved, with only a 3-mm residual gap. Furthermore, the patient achieved facial symmetry at rest. Complete eyelid closure, as well as initial signs of a spontaneous smile, was achieved after 12 months (Fig. 3). Recovery of the capacity to spontaneously blink and clinically significant synkinesis have not yet been observed. The patient did not complain of any mastication problems throughout the entire follow-up period. Electrophysiological evaluation 12 months after surgery showed ongoing reinnervation of mimic muscles, with evidence of axon sources from both donor nerve sites (Fig. 4).

Discussion

The main goals of facial rehabilitation include restoration of face symmetry, mimic muscle function, and spontaneity. In cases of absent proximal facial nerve stumps, a wide spectrum of nerves has been used for transposition including spinal, phrenic, hypoglossal, masseteric, and contralateral facial nerves with various success rates and donor morbidity [28, 30]. In 1984, Terzis introduced the "babysitter" procedure, which combines cross-facial nerve grafting with temporary partial hypoglossal to facial nerve transfer, in order to preserve mimic muscle function until contralateral reinnervation is achieved [31]. Examples of masseteric nerve utilization have been described in literature. Spira was the first to describe the use of masseteric nerve for direct restoration of lower facial nerve paralysis in 1978 [29]. Throughout the years, uses of the masseteric nerve in combined techniques have been reported. Examples include cross-facial nerve grafting with masseteric nerve coaptation [2], a "babysitter" donor [11], or a direct masseteric-facial transfer [5, 21]. Double innervation of muscular transfers with the masseteric nerve and a facial cross-graft have been published with encouraging results [4]. In our case, the masseteric nerve was used as a secondary source of innervation in a supposed incomplete recovery of the facial nerve itself. The mean time of reinnervation in cases with direct coaptation of the masseteric nerve is usually only about 4 months [3]. In our case, reinnervation was prolonged due to sural graft interposition [25]. The risk of synkinesis is lower in cases of masseteric nerve coaptation compared with the hypoglossal nerve [25].

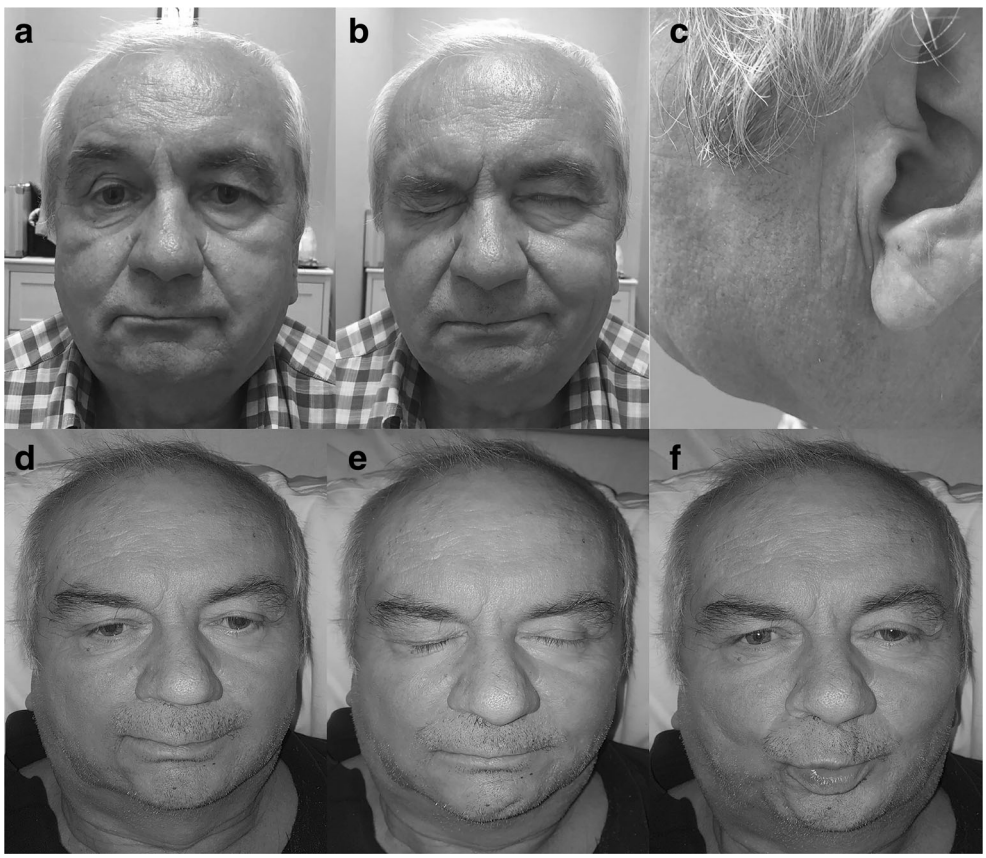

Fig. 3 Significant improvement of clinical status (**a**, **b**) together with the inconspicuous preauricular scar 9 months after surgery (**c**). The final clinical status with complete closure of the eyes 12 months after procedure (**d**–**f**)

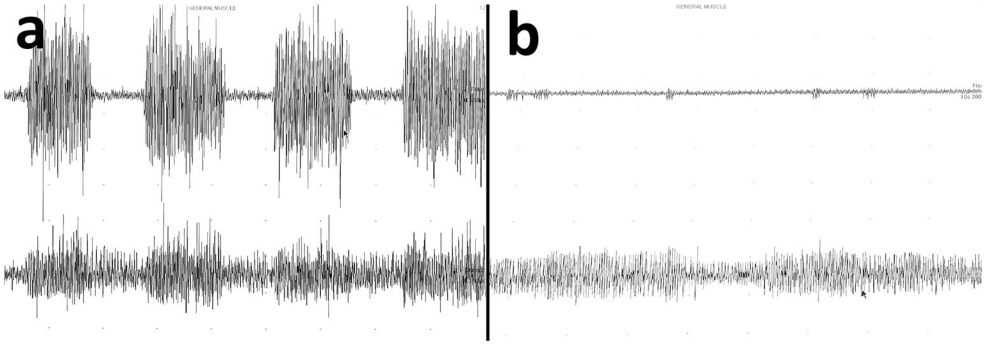

Fig. 4 Electromyography needle evaluation of temporalis muscle (upper line) and orbicularis oculi muscle (lower line) function 12 months after surgery declares independent reinnervation through both donors (**a** – trigeminal activity – voluntary biting with orbicularis oculi synkinesis, **b** – facial nerve activity – voluntary eye closure with chewing muscle relax with open mouth)

Harvesting of the masseteric nerve is straightforward and relatively simple. The position of nerve on the undersurface of the masseter muscle and its large number of axons are constants [6, 7, 17]. The nerve itself can readily be identified via electrostimulation. The subsequent scar after a preauricular incision is inconspicuous and donor morbidity is minimal. The effect on mastication is minimal and patients rarely complain about it [16].

End-to-side techniques have attracted attention because they allow additional target muscle reinnervation, with simultaneous preservation of donor nerve function [32]. Previously described, well-established techniques involving the transfer of an injured nerve to the side of an intact normal nerve should be termed end-to-side (ETS) transfers. In these cases, reinnervation occurs by collateral nerve sprouting. On the other hand, the transfer of an intact motor nerve into the side of an injured nerve should be termed a reverse end-to-side (RETS) or supercharge end-to-side (SETS) transfer [10]. These techniques were first described by Letiévant in 1873 [22]. Terzis described the SETS technique in a clinical report as a temporary "babysitter" procedure [31]. In our SETS case, reinnervation occurred by terminal axonal masseteric sprouting. Although many laboratory investigations have been performed, the in-depth mechanism of SETS is not completely understood [13, 18–20]. This fact together with the fear of signal interference, resulting in asynchronous target muscle contraction, has led to minimal implementation of this technique into clinical practice. The benefit of SETS in enhanced recovery from an incomplete nerve injury has been demonstrated by the Mackinnon group in rats [10]. This group also published the first larger successful clinical series with anterior interosseous SETS to the ulnar nerve for intrinsic musculature reinnervation [1, 8]. The most recently published large laboratory study declares that reinnervation through the SETS transfer is superior to reinnervation via the original nerve. It advocates against the use antagonistic donors in order to minimize the risk of inferior recovery [26].

The masseteric nerve satisfies this statement, with a described high recovery rate of spontaneous smile as high as 56% [15]. Our clinical and electrophysiological results correlate with this conclusion.

The main issue with neurotization of mimic muscles via the masseteric nerve is identical to all other nerves—dissociation of movement and spontaneity. The patient is first instructed to bite in order to activate his mimic muscles. Later, a complete bite is usually not necessary and patients are able to smile with an open mouth [2, 3, 24]. Successful learning of smile dissociation and mastication is the result of cortical plasticity, adaptation, and reorganization [2, 3, 9, 15, 23, 27]. In our procedure, recovery of emotional movements is most likely due to facial reinnervation itself.

The masseteric nerve was functionally preserved and can still be used in the future for reinnervation of a muscle transplant in the case of SETS failure.

Conclusion

The masseteric nerve supercharge bypass performed simultaneously with facial nerve repair is a potential option for restoration of mid-term facial paralysis in patients with a higher risk of isolated facial nerve reconstruction failure. However, viable facial musculature must be present. The masseteric bypass prevents denervation and subsequent atrophy of the musculature due to rapid activation, with minimal donor morbidity. The independent role of the facial nerve in mimic muscle activation and its role for spontaneity recovery are preserved. Larger patient series are necessary to verify the benefits of this technique.

Compliance with ethical standards

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

Patient consent The patient has consented to the submission of the case report for submission to the journal. Additional informed consent was obtained from patient for whom identifying photography is included in this article.

Ethical approval All procedures performed in study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

1. Barbour J, Yee A, Kahn LC, Mackinnon SE (2012) Supercharged end-to-side anterior interosseous to ulnar motor nerve transfer for intrinsic musculature reinnervation. J Hand Surg Am 37:2150–2159. https://doi.org/10.1016/j.jhsa.2012.07.022
2. Bianchi B, Ferri A, Ferrari S, Copelli C, Magri A, Ferri T, Sesenna E (2014) Cross-facial nerve graft and masseteric nerve cooptation for one-stage facial reanimation: principles, indications, and surgical procedure. Head Neck 36:235–240. https://doi.org/10.1002/hed.23300
3. Bianchi B, Ferri A, Ferrari S, Copelli C, Salvagni L, Sesenna E (2014) The masseteric nerve: a versatile power source in facial animation techniques. Br J Oral Maxillofac Surg 52:264–269. https://doi.org/10.1016/j.bjoms.2013.12.013
4. Biglioli F, Colombo V, Tarabbia F, Pedrazzoli M, Battista V, Giovanditto F, Dalla Toffola E, Lozza A, Frigerio A (2012) Double innervation in free-flap surgery for long-standing facial paralysis. J Plast Reconstr Aesthet Surg 65:1343–1349. https://doi.org/10.1016/j.bjps.2012.04.030
5. Biglioli F, Frigerio A, Colombo V, Colletti G, Rabbiosi D, Mortini P, Dalla Toffola E, Lozza A, Brusati R (2012) Masseteric-facial nerve anastomosis for early facial reanimation. J Craniomaxillofac Surg 40:149–155. https://doi.org/10.1016/j.jcms.2011.03.005
6. Borschel GH, Kawamura DH, Kasukurthi R, Hunter DA, Zuker RM, Woo AS (2012) The motor nerve to the masseter muscle: an anatomic and histomorphometric study to facilitate its use in facial reanimation. J Plast Reconstr Aesthet Surg 65:363–366. https://doi.org/10.1016/j.bjps.2011.09.026
7. Cotrufo S, Hart A, Payne AP, Sjogren A, Lorenzo A, Morley S (2011) Topographic anatomy of the nerve to masseter: an anatomical and clinical study. J Plast Reconstr Aesthet Surg 64:1424–1429. https://doi.org/10.1016/j.bjps.2011.05.026
8. Davidge KM, Yee A, Moore AM, Mackinnon SE (2015) The supercharge end-to-side anterior interosseous-to-ulnar motor nerve transfer for restoring intrinsic function: clinical experience. Plast Reconstr Surg 136:344e–352e. https://doi.org/10.1097/PRS.0000000000001514
9. Elbert T, Rockstroh B (2004) Reorganization of human cerebral cortex: the range of changes following use and injury. Neuroscientist 10:129–141. https://doi.org/10.1177/1073858403262111
10. Farber SJ, Glaus SW, Moore AM, Hunter DA, Mackinnon SE, Johnson PJ (2013) Supercharge nerve transfer to enhance motor recovery: a laboratory study. J Hand Surg Am 38:466–477. https://doi.org/10.1016/j.jhsa.2012.12.020
11. Faria JC, Scopel GP, Ferreira MC (2010) Facial reanimation with masseteric nerve: babysitter or permanent procedure? Preliminary results. Ann Plast Surg 64:31–34. https://doi.org/10.1097/SAP.0b013e3181999ea9
12. Fattah A, Borschel GH, Manktelow RT, Bezuhly M, Zuker RM (2012) Facial palsy and reconstruction. Plast Reconstr Surg 129:340e–352e. https://doi.org/10.1097/PRS.0b013e31823aedd9
13. Fujiwara T, Matsuda K, Kubo T, Tomita K, Hattori R, Masuoka T, Yano K, Hosokawa K (2007) Axonal supercharging technique using reverse end-to-side neurorrhaphy in peripheral nerve repair: an experimental study in the rat model. J Neurosurg 107:821–829. https://doi.org/10.3171/JNS-07/10/0821
14. Guntinas-Lichius O, Streppel M, Stennert E (2006) Postoperative functional evaluation of different reanimation techniques for facial nerve repair. Am J Surg 191:61–67. https://doi.org/10.1016/j.amjsurg.2005.05.054
15. Hontanilla B, Cabello A (2016) Spontaneity of smile after facial paralysis rehabilitation when using a non-facial donor nerve. J Craniomaxillofac Surg 44:1305–1309. https://doi.org/10.1016/j.jcms.2016.06.031
16. Hontanilla B, Marre D, Cabello A (2014) Masseteric nerve for reanimation of the smile in short-term facial paralysis. Br J Oral Maxillofac Surg 52:118–123. https://doi.org/10.1016/j.bjoms.2013.09.017
17. Hontanilla B, Qiu SS (2012) Transposition of the hemimasseteric muscle for dynamic rehabilitation of facial paralysis. J Craniofac Surg 23:203–205. https://doi.org/10.1097/SCS.0b013e31824190a6
18. Isaacs J, Allen D, Chen LE, Nunley J 2nd (2005) Reverse end-to-side neurotization. J Reconstr Microsurg 21:43–48; discussion 49-50. https://doi.org/10.1055/s-2005-862780
19. Isaacs JE, Cheatham S, Gagnon EB, Razavi A, McDowell CL (2008) Reverse end-to-side neurotization in a regenerating nerve. J Reconstr Microsurg 24:489–496. https://doi.org/10.1055/s-0028-1088230
20. Kale SS, Glaus SW, Yee A, Nicoson MC, Hunter DA, Mackinnon SE, Johnson PJ (2011) Reverse end-to-side nerve transfer: from animal model to clinical use. J Hand Surg Am 36:1631–1639 e1632. https://doi.org/10.1016/j.jhsa.2011.06.029
21. Klebuc MJ (2011) Facial reanimation using the masseter-to-facial nerve transfer. Plast Reconstr Surg 127:1909–1915. https://doi.org/10.1097/PRS.0b013e31820e9138
22. Letievant E (1873) Traite Des Sections Nerveuses, Paris
23. Lifchez SD, Matloub HS, Gosain AK (2005) Cortical adaptation to restoration of smiling after free muscle transfer innervated by the nerve to the masseter. Plast Reconstr Surg 115:1472–1479; discussion 1480-1472
24. Manktelow RT, Tomat LR, Zuker RM, Chang M (2006) Smile reconstruction in adults with free muscle transfer innervated by the masseter motor nerve: effectiveness and cerebral adaptation. Plast Reconstr Surg 118:885–899. https://doi.org/10.1097/01.prs.0000232195.20293.bd
25. Murphey AW, Clinkscales WB, Oyer SL (2018) Masseteric nerve transfer for facial nerve paralysis: a systematic review and meta-analysis. JAMA Facial Plast Surg 20:104–110. https://doi.org/10.1001/jamafacial.2017.1780
26. Nadi M, Ramachandran S, Islam A, Forden J, Guo GF, Midha R (2018) Testing the effectiveness and the contribution of experimental supercharge (reversed) end-to-side nerve transfer. J Neurosurg:1–10. https://doi.org/10.3171/2017.12.JNS171570
27. Rubin LR, Rubin JP, Simpson RL, Rubin TR (1999) The search for the neurocranial pathways to the fifth nerve nucleus in the reanimation of the paralyzed face. Plast Reconstr Surg 103:1725–1728
28. Socolovsky M, Martins RS, di Masi G, Bonilla G, Siqueira M (2016) Treatment of complete facial palsy in adults: comparative study between direct hemihypoglossal-facial neurorrhaphy, hemihipoglossal-facial neurorrhaphy with grafts, and masseter to facial nerve transfer. Acta Neurochir 158:945–957; discussion 957. https://doi.org/10.1007/s00701-016-2767-7
29. Spira M (1978) Anastomosis of masseteric nerve to lower division of facial nerve for correction of lower facial paralysis. Preliminary report. Plast Reconstr Surg 61:330–334

30. Terzis JK, Konofaos P (2008) Nerve transfers in facial palsy. Facial Plast Surg 24:177–193. https://doi.org/10.1055/s-2008-1075833
31. Terzis JK, Tzafetta K (2009) The "babysitter" procedure: minihypoglossal to facial nerve transfer and cross-facial nerve grafting. Plast Reconstr Surg 123:865–876. https://doi.org/10.1097/PRS.0b013e31819ba4bb
32. Tos P, Colzani G, Ciclamini D, Titolo P, Pugliese P, Artiaco S (2014) Clinical applications of end-to-side neurorrhaphy: an update. Biomed Res Int 2014:646128. https://doi.org/10.1155/2014/646128
33. Ylikoski J, Hitselberger WE, House WF, Sanna M (1981) Degenerative changes in the distal stump of the severed human facial nerve. Acta Otolaryngol 92:239–248

Comments

This article describes a surgical method of direct suture repair of a completely transected facial nerve combined with a supercharge reverse end to side repair in which the master branch of the trigeminal nerve is cut and using a sural nerve interposition graft anastomosed into the side of the facial nerve distal to the primary repair site. The clinical outcome given the length of time from the original injury is quite good. The authors convincingly demonstrate dual innervation of the facial muscles with progressive normalization of voluntary control of the facial muscles over time. It is another useful tool in the peripheral nerve surgeon's tool box.

Michel Kliot
CA, USA