Comparison of Direct Side-to-End and End-to-End Hypoglossal-Facial Anastomosis for Facial Nerve Repair

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■ BACKGROUND: **The hypoglossal facial anastomosis (HFA) is the gold standard for facial reanimation in patients with severe facial nerve palsy. The major drawbacks of the classic HFA technique are lingual morbidities due to hypoglossal nerve transection. The side-to-end HFA is a modification of the classic technique with fewer tongue-related morbidities.**

■ OBJECTIVES: **In this study we compared the outcome of the classic end-to-end and the direct side-to-end HFA surgeries performed at our center in regards to the facial reanimation success rate and tongue-related morbidities.**

■ METHODS: **Twenty-six successive cases of HFA were enrolled. In 9 of them end-to-end anastomoses were performed, and 17 had direct side-to-end anastomoses. The House-Brackmann (HB) and Pitty and Tator (PT) scales were used to document surgical outcome. The hemiglossal atrophy, swallowing, and hypoglossal nerve function were assessed at follow-up.**

■ RESULTS: **The original pathology was vestibular schwannoma in 15, meningioma in 4, brain stem glioma in 4, and other pathologies in 3. The mean interval between facial palsy and HFA was 18 months (range: 0–60). The median follow-up period was 20 months. The PT grade at follow-up was worse in patients with a longer interval from facial palsy and HFA (*P* value: 0.041). The lesion type was the only other factor that affected PT grade (the best results in vestibular schwannoma and the worst in the other pathologies group, *P* value: 0.038). The recovery period for facial tonicity was longer in patients with radiation therapy before HFA (13.5 vs. 8.5 months) and those with a longer than 2-year interval from facial palsy to HFA (13.5 vs. 8.5 months). Although no significant difference between the side-to-end and the end-to-end groups was seen in terms of facial nerve functional recovery, patients from the side-to-end group had a significantly lower rate of lingual morbidities (tongue hemiatrophy: 100% vs. 5.8%, swallowing difficulty: 55% vs. 11.7%, speech disorder 33% vs. 0%).**

■ CONCLUSION: **With the side-to-end HFA technique the functional restoration outcome is at least as good as that following the classic end-to-end HFA, but the complications related to the complete hypoglossal nerve transection can be avoided. Best results are achieved if this procedure is performed within the first 2 years after facial nerve injury. Patients with facial palsy of longer duration also have the chance for good functional restoration after HFA.**

INTRODUCTION

Facial palsy is one of the most devastating complications that may occur after surgery of the cerebellopontine angle and brain stem lesions. In spite of the striking development in microsurgical techniques and remarkable advances in intraoperative facial nerve monitoring, facial paralysis of varying degrees is not an uncommon postoperative event (7, 8, 42).

Various surgical interventions have been proposed for reanimation of the paralyzed face ranging from static corrections of asymmetry to dynamic reanimation procedures. It is widely

Key words
- Facial nerve repair
- Facial palsy
- Facial reanimation
- Hypoglossal nerve
- Hypoglossal-facial anastomosis

Abbreviations and Acronyms
HB: House-Brackmann
HFA: Hypoglossal facial anastomosis
IAC: Internal auditory canal
ICA: Internal carotid artery
PT: Pitty and Tator
SCM: Sternocleidomastoid muscle

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accepted that, when possible, primary end-to-end facial nerve repair with or without an interposition graft offers the best hope for recovery, both in intracranial and extracranial facial nerve transections (11, 45, 46). However, such a repair is impossible when the proximal stump of the facial nerve at the brain stem is not available, in case of destruction of the intrapontine facial nucleus and when the facial nerve is anatomically preserved but the patient has inadequate recovery of facial paresis due to internal axonotmesis and subsequent suboptimal regeneration (11, 15, 30, 32-34).

In these cases facial crossover neurotization through other cranial nerves may be considered. In 1895, Charles Alfred Balance was the first to perform facial to spinal accessory crossover anastomosis (5, 40-42). In 1901, Körte and Bernhardt performed the first hemihypoglossal-facial anastomosis (12, 19, 41). The facial and hypoglossal nerves have a cortical topographic proximity in the motor cortex. Both nerves receive afferent input from the trigeminal reflex arcs and act synergistically in the coordination of some mimetic and prandial functions, and both contain myelinated motor fibers with similar fascicular anatomy (3, 4). These features made the hypoglossal-facial anastomosis (HFA) the most successful crossover facial nerve repair (11). Nevertheless, the classic end-to-end HFA is associated with inevitable hemiglossal atrophy and persistent speech, mastication, and/or swallowing difficulties that interfere with daily life (4, 12, 21, 22).

However, over the past 2 decades many variants of this procedure have been developed to reduce morbidities of the tongue function (3, 5, 7, 17, 19, 21, 43, 44, 47). In 1991, May et al. reported favorable results when using only half of the hypoglossal nerve joined to the extracranial facial nerve by a jump-cable graft (23). In 1994, Cusimano and Sekhar proposed a partial HFA by longitudinal splitting of the hypoglossal nerve (11).

In 1997, Sawamura et al. and in 1999, Darrouzet et al. proposed hemihypoglossal-facial anastomosis with rerouting of the intratemporal part of the facial nerve without using a nerve graft (4, 12, 33). With this technique the squeals of the hemiglossal atrophy are reduced and the limitations of the May technique are also covered.

Since then some studies reported application of the direct side-to-end HFA for facial reanimation (4, 12, 13, 15, 22, 31, 33, 34, 42). In this article we present our experience with direct side-to-end HFA via mobilization of the intramastoid facial nerve and compare the results with those of our classic end-to-end HFA patients. We also evaluate the role of some disputable factors on the results of facial reanimation.

MATERIAL AND METHODS

Twenty-six patients with iatrogenic facial palsy were retrospectively enrolled, including 20 male and 6 female patients with the average age of 38 years old (ranging from 2–69 years). The original lesion was vestibular schwannoma in 15, meningioma in 4, brain stem glioma in 4, and other pathologies in 3 (skull base metastasis from breast cancer, endolymphatic sac carcinoma, and adenoid cystic carcinoma). The preoperative grade of facial palsy was documented as House-Brackmann (HB) score, and all other cranial nerve deficits were documented. For patients with a longstanding facial palsy (beyond 2 years), electromyography of the facial muscles was performed. The HFA surgery was offered only when typical spontaneous (positive sharp waves and fibrillation potentials) and insertional activities were present. End-to-end HFA was done for 9 patients, while in the other 17 a side-to-end HFA was done by a single neurosurgeon (MS). The HB and Pitty and Tator (PT) grades (Table 1) (30) were used to document the surgical outcome from 6 months to 2 years after the operation. Tonicity of facial musculature was documented by assessing the nasolabial fold and rest symmetry of the face and then compared with previous visits. At each postoperative visit the presence of hemiglossal atrophy, swallowing, and hypoglossal nerve function were evaluated.

Statistical analysis was performed using the SPSS software (version 19.0 for Windows; SPSS, Inc., Chicago, Illinois, USA). The Kruskal-Wallis nonparametric test was used to determine the correlations among the type of original lesion, age, time between nerve lesion and surgery, and the outcome, as evaluated by the HB and PT grading systems. A comparison of surgical results from the two techniques of HFA was made with the Mann-Whitney U test. Multivariate analysis was done using an ordinal regression model for HB and PT grades as the target variables. Differences were considered significant at a P value of less than 0.05.

Surgical Anatomy

The peripheral facial nerve appears at the pontomedullary sulcus and consists of six portions: 1) from brain stem laterally toward the internal auditory canal (IAC) (cisternal part), 2) the part inside the IAC (meatal part), 3) the part running between the cochlea and the vestibule (labyrinthine part) and then 4) on the medial aspect of the tympanic cavity (tympanic part), 5) the part descending in the fallopian canal of the mastoid bone (mastoidal part), and 6) exiting the skull through the stylomastoid foramen to become the terminal extracranial part (7). In the deep cervical area, it usually

Table 1. Pitty and Tator Classification of Facial and Hypoglossal Nerve Function After Hypoglossal-Facial Anastomosis

Outcome	Description
Good	Good facial symmetry at rest Complete voluntary eye closure Mild to moderate mouth movement Minimal or absent synkinesis or mass movement Minimal or absent dysfunction in eating, swallowing or speech, attributable to hypoglossal nerve section Feeling of major benefit from the procedure
Fair	Fair facial symmetry at rest Unable to obtain satisfactory closure of the eye Marked synkinesis or mass movement Moderate dysfunction in eating, swallowing, or speech, attributable to hypoglossal nerve section Feeling of limited benefit from the procedure
Poor	Gross facial asymmetry at rest Total inability to close the eye No mouth movement Marked synkinesis or mass movement Feeling of no benefit from the procedure
Failure	No evidence of reinnervation

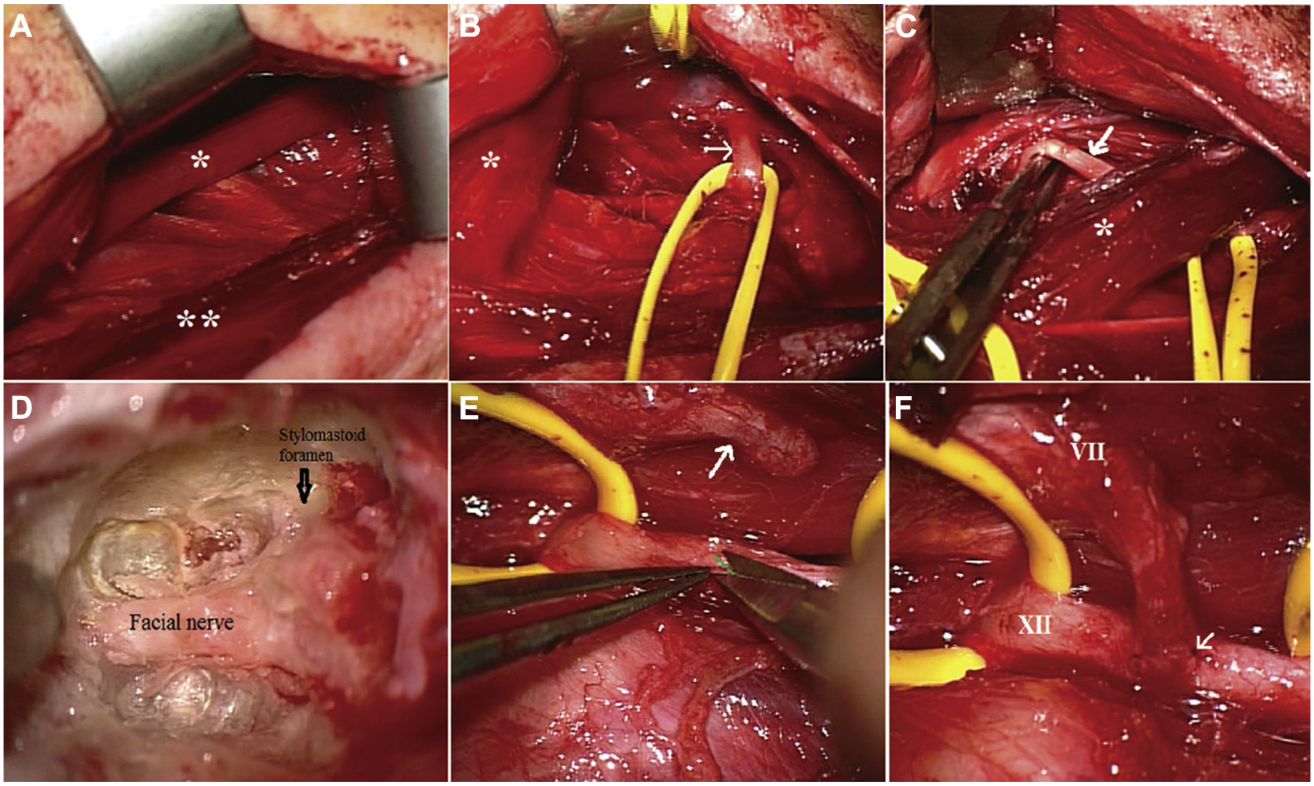

Figure 1. Intraoperative views of the direct side-to-end hypoglossal facial anastomosis. (**A**) Cervical dissection is followed between sternocleidomastoid (*two asterisks*) and posterior belly of digastric muscle (*asterisk*). (**B**) After retraction of the posterior belly of digastric (*asterisk*) and dissection deep to this muscle, the distal portion of hypoglossal nerve (*arrow*) is found. (**C**) The hypoglossal nerve is followed proximally to find the vertical segment of the nerve (*arrow*). (**D**) A limited anterior mastoidectomy is done, and the facial nerve is exposed within the fallopian canal. (**E**) The facial nerve is cut proximally and reflected down (*arrow*), and the dorsal aspect of the hypoglossal nerve is incised in a posterior oblique direction. (**F**) The facial nerve is anastomosed with the dorsal aspect of the hypoglossal nerve using epineurial microsutures.

appears ventrally to the mastoid tip and gives off numerous tiny branches, among which the two motor branches to the posterior belly of the digastric muscle (digastric branch) and the auricular and occipital muscles (posterior auricular branch) are used as landmarks to the main trunk (3).

The fascicles of the hypoglossal nerve originate at the preolivary sulcus and meet and course anterolaterally and downward through the hypoglossal foramen to exit the skull (7). In its proximal course, it runs underneath the posterior belly of the digastric muscle and turns anteriorly toward the tongue at the level of digastric intermediate tendon (7). In extremely high cervical areas the hypoglossal nerve runs parallel to the vagus and accessory nerves, dorsal to the internal carotid artery (ICA) and deep to the internal jugular vein (3). At this point it is difficult to differentiate among these nerves, but more caudally the hypoglossal nerve separates and gives off the descending branch to the ansa cervicalis and crosses the ICA.

Direct Side-to-End HFA Technique

The patient is positioned in supine with the head turned away from the surgeon. The head is tilted so that the mastoid tip becomes the highest point in the surgical field. We usually re-explore the same postauricular incision from the initial operation and extend it caudally along the anterior border of the sternocleidomastoid muscle (SCM) until just above the angle of mandible. The greater auricular nerve that runs in the subcutaneous fat tissue is dissected and preserved. The parotid gland is dissected and released anteriorly.

Attachments of the SCM to the mastoid are subperiosteally dissected and retracted posteriorly (Figure 1A). The mastoid tip is exposed by removing the muscle attachments. Entry to the deep cervical area was done in an area confined anteriorly to the parotid gland, posteriorly to the SCM anterior margin, and superiorly to the mastoid tip. The hypoglossal nerve is found deep to the posterior belly of the digastric muscle at the caudal end of the incision. It is confirmed with a nerve stimulator (Figure 1B) and followed proximally (Figure 1C).

Because identification of an atrophic facial nerve distal to the stylomastoid foramen could be difficult, the mastoidal segment of the facial nerve is first identified by performing a limited mastoidectomy. Partial mastoidectomy of the anterior part of the mastoid process is done using a high-speed drill and a diamond burr. A thin layer of bone is left over the facial nerve, which is then removed by a microdissector. The facial nerve is exposed in the fallopian canal up to its external genu and geniculate ganglion (Figure 1D).The stylomastoid foramen is opened, and the nerve is released from the thick surrounding connective tissue at this site and followed down to the pes anserinus in parotid gland. The facial nerve is obliquely cut at its external genu and reflected on to the hypoglossal nerve under the digastric muscle. Under high magnification the superior half of the hypoglossal nerve is obliquely divided to accommodate the tip of the facial nerve stump (Figure 1E). The distal end of the facial stump is trimmed from the epineurium and coapted with the proximal end of the hypoglossal nerve without any tension. These two sites are then connected to each other using two tiny 9-0 or 10-0 nylon epineurial sutures (Figure 1F). The anastomosis site is circumferentially covered by a layer of fibrin glue. After complete hemostasis, the wound is closed in layers and an open drainage is placed. Figure 2 schematically depicts the surgical technique used for the side-to-end HFA.

RESULTS

The preoperative HB grade was 5 in 11 patients and 6 in the remaining 15 patients. The interval between occurrence of facial palsy and HFA was 18 months on average. In one patient the HFA was performed during the primary surgery for tumor removal. The longest interval was 60 months. Seven patients (27%) had an interval longer than 2 years. Eight patients had a history of radiotherapy/radiosurgery after their initial surgery. The median follow-up period was 20 months, ranging from 11 to 43 months.

The last follow-up HB grade was 2 in 1 patient (3.8%), 3 in 18 patients (69.3%), 4 in 5 patients (19.2%), and 5 in 2 patients (7.7%). The last follow-up PT grade was good in 19 patients (73%), fair in 3 (11.5%), poor in 3 (11.5%), and failure in 1 (3.8%).

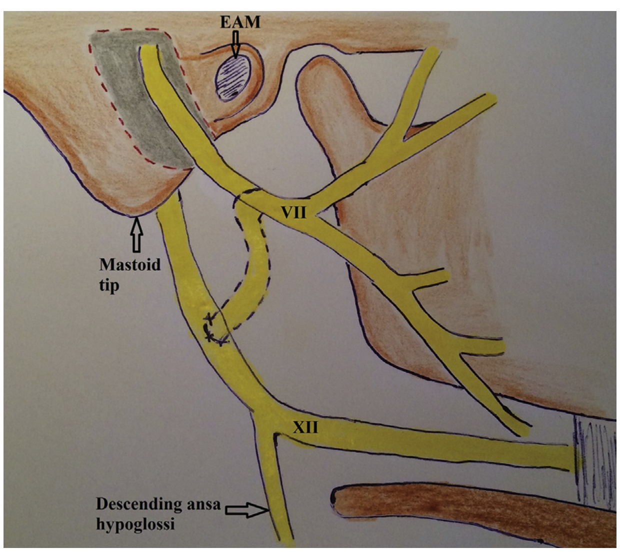

Figure 2. Schematic drawing of the technique of the side-to-end hypoglossal-facial anastomosis. The *dashed line* delimits the area of mastoidectomy. EAM, external auditory meatus.

The average time for recovery of the facial muscle tonicity and improvement of rest symmetry was 9.6 months (range 5–15) from the HFA.

The last follow-up HB grade in the end-to-end group was 3 in 5 patients, 4 in 3 patients, and 5 in 1 patient. In the end-to-side group, 1 patient had HB grade 2, 13 patients had grade 3, 2 had grade 4, and 1 had grade 5 HB in the last follow-up. The observed difference in outcome between the two groups was not statistically significant.

At the last follow-up, the PT grade of the end-to-end group was good in 5, fair in 2, and poor in 2 patients, while in the end-to-side group it was good in 14, fair in 1, poor in 1, and failure in 1. The observed difference in PT grades between the two groups was not statistically significant.

Only 1/17 of direct side-to-end patients experienced a mild lingual hypotrophy, while in the end-to-end group 2 patients had mild atrophy and 7/9 had moderate to severe atrophy (P value < 0.000). In the end-to-end group 5 patients (55%) reported suffering from having some food residue in the oral cavity after swallowing, while this occurred just in 2 patients (11.7%) of the side-to-end group (P value: 0.028). Difficulty in articulation and speech was seen only after end-to-end HFA (3/9 patients).

In this study we found no significant relationship between the age of the patients and the HB and PT grades at the last follow-up.

The time interval from occurrence of facial palsy to HFA operation was not directly related to the outcome, evaluated with the HB scale, but the PT grade was significantly better in those with a shorter interval from palsy to repair (P value: 0.041). The PT outcome grade in patients operated on within 2 years after the facial injury was good in 16 patients, fair in 1, and poor in 2. In the subgroup of patients, operated on later, it was good in 3, fair in 2, poor in 1, and failure in 1 (P value: 0.016). All 5 later patients who had good or fair results despite the late reconstruction had an anatomically preserved facial nerve and an HB grade of 5 after the initial surgery.

Table 2 presents the clinical features and outcome parameters of the patients in regards to the tumor type. The tumor type was significantly associated with the HB and PT grades at the last follow-up. The patients with vestibular schwannomas had higher HB and PT grades at the last follow-up than the patients with other tumors (P value: 0.02 and 0.006, respectively).

The recovery period of the facial tonicity was significantly longer in patients who had received radiotherapy/radiosurgery (13.5 vs. 8.5 months, P value: 0.009). Previous radiation therapy, however, did not show any relation with the final HB and PT grades.

The interval from facial palsy to HFA was the only other factor that affected the recovery time of facial tonicity (Pearson correlation coefficient: 0.674, P value: 0.002). The mean interval for recovery of facial tonicity was 13.6 months in patients with more than 2 years' interval between facial palsy and HFA, while it was 8.8 months in those with less than 2 years' interval (P value: 0.008).

The multivariate analysis showed that HB grade at follow-up was not related to any of the independent variables. The PT grade, however, was significantly correlated to the time interval from facial palsy and HFA (P value: 0.041) and to the tumor type. The best results were seen among patients with vestibular schwannoma and the worst ones in the *other pathology* group, P value: 0.038.

Table 2. Clinical Data of the Patients According to the Type of Their Original Lesion

Original Tumor Type	Number of Patients	Mean Age	Preoperative HB Grade	Interval from Palsy to HFA	HFA Type	HB in Last FU	PT Grade in Last FU	Lingual Complications	
								e-e Group	s-e Group
VS	15	41.9	Grade 5:7 Grade 6:8	16.6	e-e: 5 s-e: 10	Grade 2:1 Grade 3:13 Grade 4: 1	Good: 14 Fair: 1	HA: 5 SD: 2 Speech dis.: 1	HA:1 SD: 0 Speech dis.: 0
Meningioma	4	50.7	Grade 5:2 Grade 6:2	7.3	e-e: 2 s-e: 2	Grade 3:2 Grade 4: 2	Good: 2 Fair: 1 Poor: 1	HA: 2 SD: 1 Speech dis.: 1	HA: 0 SD: 0 Speech dis.: 0
BSG	4	17	Grade 5:1 Grade 6:3	30	e-e: 1 s-e: 3	Grade 3:2 Grade 4: 2	Good: 2 Fair: 1 Poor: 1	HA: 1 SD: 1 Speech dis.: 1	HA: 0 SD: 1 Speech dis.: 0
Others	3	29.3	Grade 5:1 Grade 6:2	23.6	e-e: 1 s-e: 2	Grade 3:1 Grade 5: 2	Good: 1 Poor: 1 Failure: 1	HA: 1 SD: 1 Speech dis.: 0	HA: 0 SD: 1 Speech dis.: 0

HB, House-Brackmann; HFA, hypoglossal facial anastomosis; FU, follow-up; PT, Pitty and Tator; e-e, end to end; s-e, side to end; VS, vestibular schwannoma; HA, Hemiatrophy; SD, Swallowing disorder; BSG, brain stem glioma.

Summary of Results

The PT grade at follow-up is significantly affected by the time interval from facial palsy to HFA and also by the lesion type. The recovery period for facial tonicity is prolonged in patients treated with radiotherapy/radiosurgery before HFA and in those with a longer than 2-year interval from facial palsy to the HFA.

The anastomotic technique, end-to-end or side-to-end, had similar efficacy in regards to facial nerve recovery, but the side-to-end technique had a significantly lower rate of lingual morbidities.

DISCUSSION

Reanimation of the paralyzed face is still a great challenge despite all recent advances. A transected nerve will probably never function again as perfectly as it did originally. Still, the recovery can be very good (32). Since the late 19th century, surgical crossover neurotization of the damaged facial nerve was attempted using the phrenic nerve, glossopharyngeal nerve, contralateral facial nerve, spinal accessory nerve, and hypoglossal nerve (9, 14, 26, 27, 47). Due to the undesirable side effects following the sacrifice of the phrenic and glossopharyngeal nerves (9) and the lower rate of efficacy reported for the spinal accessory and the contralateral facial nerves' usage as donor nerves (1, 25, 27, 38, 48), HFA remains the preferred technique for properly selected patients (11, 29, 30).

Since the introduction of the HFA procedures, there has been a debate on the advantages of the two techniques: the end-to-end and the end-to-side nerve repair (41). However, in the classic end-to-end anastomotic technique the hypoglossal nerve is completely transected, causing hemiglossal atrophy and morbidities due to hemilingual function, particularly when the facial nerve functional recovery is less than normal (22, 41). Therefore this is technique is contraindicated in patients who have bilateral palsies or contralateral lingual weakness, in those who have concomitant lower cranial nerve or fifth nerve impairments, in patients who have an underlying risk of lower cranial neuropathies (e.g., in neurofibromatosis type 2, or in those who have a profession for which speech is essential (4, 12, 22, 34).

To circumvent the tongue-related morbidities, May et al. reported favorable results using hemihypoglossal-facial nerve connection through an interposition jump-cable graft (23). This technique, however, has the disadvantages of morbidity at the donor nerve site and necessitates two lines of nerve sutures that cause additional scarring and impede axonal regrowth. Fewer myelinated axons cross the reconstruction site (12, 15, 34, 35).

Cusimano and Sekahr (11) and Arai et al. (2) used a longitudinal hypoglossal nerve split, routed cranially for direct HFA at the stylomastoid foramen. Using this technique, good results in terms of facial reanimation were achieved but mild to moderate hemiglossal atrophy was reported in all patients. The hypoglossal nerve split additionally injures the axons because the hypoglossal nerve trunk at the high cervical area is exclusively monofascicular and the longitudinal split may transect many interweaving axons (3, 20, 22, 39).

Drilling of the mastoid process exposes an additional length of around 1.5 cm from the mastoidal part of the facial nerve. If the length of the extracranial part of the facial nerve from stylomastoid foramen to pes anserinus is added to this, the total available length of the facial nerve will be more than 3 cm (3, 7, 34). In a cadaveric study Asaoka et al. confirmed that this length is always longer than the distance between pes anserinus of the facial nerve and the hypoglossal nerve (<1.5 cm) (3). Therefore by reflecting the released mastoidal and prebifurcation extracranial facial nerve part on the dorsal surface of the hypoglossal nerve, a tensionless coaptation may be easily possible.

The diameter of the donor and the recipient nerves is an important factor in performing successful nerve anastomosis (32). In an anatomic study, the diameter of the intact facial nerve was 61.5% of that of the hypoglossal nerve, whereas the cross-sectioned area of the injured facial nerve was less than 50% (3).

According to histomorphometric studies, the number of myelinated axons in the hypoglossal nerve is about 1.5–2 times that of the intact facial nerve (6, 20) and this ratio is even higher considering the decreased number of myelinated axons in the injured facial nerve (3). These findings confirm that only half of the normal hypoglossal nerve could be sufficient for an HFA. Moreover, because the facial nerve should be transected intraoperatively to perform a HFA, degeneration of the facial nerve distal stamp will occur in all the patients, disregarding their preoperative facial nerve integrity and axonal content.

The dorsal aspect of the hypoglossal nerve at high cervical level usually contains motor fibers of the communicating branch from the first cervical spinal nerve that do not contribute to glossal function (3, 34). Therefore an incision at the posterior aspect of the hypoglossal nerve may spare the fibers responsible for lingual function. The results from side-to-end HFA, demonstrated in the current paper, prove that it does not cause permanent lingual dysfunction.

The most common grading system for facial nerve function is the House-Brackmann (HB) scale. However, this grading is adequate to assess facial nerve recovery when a lesion in continuity is present (Bell palsy, delayed post-traumatic facial paresis) or after a seven-to-seven nerve repair. It was not designed to assess the facial nerve recovery after a heterograft (12, 15, 18).This system is particularly inadequate in assessing intermediate facial function with varying degrees of facial asymmetry (18) and does not take into consideration the psychological satisfaction of the patient of his or her regained facial functions. May et al. developed a specialized facial nerve grading system (24), but it has also been limited by its subjectivity (18). By modifying some previous grading systems, Pitty and Tator developed a classification of outcome after HFA (see **Table 1**). This classification is based on assessing the facial muscle contraction and the presence of the nasolabial fold, hypoglossal nerve–related symptoms, abnormal movements, and psychological and emotional aspects (30). The application of this system obviates the need for using another scaling for the degree of hypoglossal function (22) and gives an overall view of the outcome after HFA. The results of our study show that this PT grading is superior to the HB grading system in relation to clinical factors that affect the ultimate outcome after HFA.

In a meta-analysis of 293 patients with end-to-end HFA and 71 patients with side-to-end HFA (including 57 with interposition graft and only 14 with direct HFA), a grade II HB was achieved in 12.6%, grade III in 50.8%, grade IV in 28.9%, grade V in 6.3%, and grade VI in 1.4%. Patients with facial palsy due to gunshot wounds or facial neuroma had an outcome worse than those with vestibular schwannomas. Anastomosis performed within 1 year after facial palsy provided better recovery. The rate of tongue atrophy was greater in patients with end-to-end HFA, but no major differences between the end-to-end and the end-to-side interpositional jump grafting techniques in terms of tongue function were found (45). **Table 3** presents the results of the published reports of the direct end-to-side HFA.

The importance of the duration between the occurrence of facial nerve injury and the repair for the outcome is now accepted by most authors (9, 10, 12, 18, 22, 30, 32, 34). Our results also show that an interval of less than 2 years significantly improves the final outcome. In this study, the mean interval of repair was 18 months, which is due to the late referral of some patients who have been operated on elsewhere for their primary lesion. We would consider a shorter interval to perform the HFA if they would have been referred to us earlier after the paresis. One important finding was that even if the period after the facial injury is more than 2 years, there is still a chance for functional recovery. There is no definite period of delay beyond which the HFA becomes ineffective (33, 45). Interestingly, all patients operated on later who benefited from the reconstructive procedure had an anatomically preserved but nonfunctioning facial nerve. Sawamura et al. also noted that in two of the three patients who benefited from HFA more than 2 years after facial palsy, the facial nerve continuity was preserved (33). Some explanations support this fact, including shorter distance between the facial nerve muscles; physiological differences between facial and limb musculature, which explain the relative tolerance of facial muscles to longer denervation periods (36); axonal sprouting from the contralateral facial nerve (17, 37); and clinically imperceptible trophic influence of the anatomically preserved facial nerve (22, 33), which maintains the integrity of myoneural junction during denervation. This underscores the importance of preserving the continuity of the facial nerve during tumor resection.

The time for recuperation of the tonus of facial musculature and rest symmetry of the face was longer in patients who had a longer delay period between facial injury and repair and in those who received radiation therapy before the HFA. Therefore a protracted course of recovery should be expected and discussed with these patients. Darrouzet et al. also reported longer recovery periods in those with longer delay periods (12). Venail et al. reported a significant improvement of the facial function up to 2 years after side-to-end HFA (42). We agree with Rebol et al. and Catli et al. that significant improvement in facial function can occur even after 3 years of the operation, and the definitive results can only be observed after 2–3 years (8, 31). Considering the adverse effect of radiotherapy on facial nerve recovery rate, we recommend radical tumor removal and performing an early HFA rather than a more conservative tumor removal, leaving the patient with both facial palsy and tumor residue in the posterior fossa.

Our results revealed that patients with facial palsy after resection of vestibular schwannoma had better results than those with meningiomas and brain stem glioma. Worst outcome was seen in three patients from the *other pathologies* group: one with skull base metastasis from breast cancer, one with endolymphatic sac carcinoma, and one with adenoid cystic carcinoma. Pitty et al. and Ylikoski et al. reported lower recovery rates after HFA in patients with meningiomas in comparison with vestibular schwannomas, even with relatively short delays between facial nerve injury and repair (30, 46). The histopathological finding was a major fibrotic change in the nerve (46). Unlike our results, Malik et al. reported no impairment of facial reanimation in four cases with malignancy (28). The poor results seen in the *other pathologies* group could be explained by the malignant and/or invasive nature of the lesions in this group, which may affect the regeneration potential of the proximal stump of the facial nerve.

According to our results, the side-to-end HFA is at least as effective as the classic end-to-end procedure in facial reanimation. At the same time, the rate of lingual atrophy and difficulty in the oral phase of swallowing is significantly lower. Therefore we

Table 3. Summarized Results of the Published Series Using Direct Side-to-End Hypoglossal-Facial Anastomosis

Author	Publication Year	Number of Cases	Facial Reanimation Outcome	Hypoglossal Nerve Outcome
Sawamura & Abe (33)	1997	4	III: 75% IV: 25%	No hemilingual atrophy and no clinical problem
Atlas & Lowinger (4)	1997	3	III: 100%	No hemilingual atrophy and no clinical problem
Donzelli et al. (13)	2003	3	III: 33.3% IV: 66.6%	Slight lingual hypotrophy in all, but no clinical problem
Franco-Vidal et al. (16)	2006	15	III: 73% IV: 20% V: 7%	Clinical lingual problem in 6.7%
Rebol et al. (25)	2006	5	III: 40% IV: 20% V: 20% VI: 20%	No hemilingual atrophy and no clinical problem
Ferraresi et al. (15)	2006	2	II: 100%	No hemilingual atrophy and no clinical problem
Martins et al. (22)	2008	24	III: 70.8% IV: 25% V: 4.2%	30.2% mild lingual atrophy, 4.2% clinical lingual problem
Venail et al. (42)	2009	12	III: 50% IV: 50%	Lingual hypotrophy in 16.7% and hemiparesis in 41.7%
Slattery III et al. (34)	2014	19	III: 36.8% IV: 47.9% V: 15.8%	5.2% lingual problem
Ours (32)	2014	17	II: 5.8% III: 76.5% IV: 11.7% V: 5.8%	Mild lingual hypotrophy in 5.8% and clinical problem in 11.7%

believe that the classic end-to-end HFA could be replaced by the direct side-to-end HFA as the "gold standard" to reanimate the face in management of the proximal facial nerve injuries.

CONCLUSION

The facial reanimation outcome after the side-to-end HFA is at least as good as that following the classic end-to-end HFA. Major complications caused by the complete transection of the hypoglossal nerve, such as lingual atrophy and difficulty in the oral phase of swallowing, can be avoided with the side-to-end technique. Best results are achieved if this procedure is performed within the first 2 years after facial nerve injury. Even when facial palsy is of longer duration, facial reanimation is indicated because good functional restoration may be achieved, particularly in cases of vestibular schwannomas.

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