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Postoperative functional evaluation of different reanimation techniques for facial nerve repair

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Abstract

Background: The facial nerve function after facial-facial nerve anastomosis, grafting, hypoglossal-facial nerve anastomosis, hypoglossal-facial interpositional jump nerve anastomosis, or a combined approach was analyzed.

Methods: Facial function was assessed after operation using a 7-point visual analog scale (VAS) and by electromyography (EMG) in 53 patients. The final result was judged by May's facial nerve grading system.

Results: Voluntary EMG activity occurred on average 4.52 ± 1.31 months after operation. Initial facial movements were visible after 5.41 ± 1.80 months. Facial function related to the VAS finally reached 44% of normal value. The result was judged May's grade I in 13%, grade II in 34%, grade III in 28%, and grade IV in 25% of patients. A significant difference in outcome between different reconstruction types was not seen. Age over 60 years was related to worse outcome.

Conclusions: A correct selection of the best method in the individual situation presumed, all analyzed facial reanimation techniques seem to lead nearly similar and satisfactory results.

Keywords: Facial nerve; Facial paralysis; Nerve repair; Hypoglossal nerve; Nerve graft; Nerve anastomosis

Facial expression is an important part of human communication. Loss of facial symmetry and facial expression after facial nerve injury have an great impact on the psychosocial conditions of the patients [1]. Therefore, facial nerve reconstruction including restitution of the facial symmetry and facial expression is a great surgical challenge. A variety of surgical techniques is available [2]. Direct tension-free end-to-end facial-facial nerve anastomosis is the method of choice in cases of minor nerve resection because of tumor infiltration after iatrogenic or traumatic facial nerve injury [3,4]. In patients with a head and neck neoplasm, a tension-free primary repair is often not possible. In these cases, a facial nerve interposition graft is indicated [4,5]. Typically, the greater auricular nerve or the sural nerve is used. Especially, parotid cancer surgery often results in a segmental defect within the peripheral facial nerve fan requiring several nerve grafts. When the proximal facial nerve in its intracranial or intratemporal portion is not available or in cases with very long defects not favorable for grafting, a reconstruction with the hypoglossal nerve by hypoglossal-facial nerve anastomosis is an effective alternative [6,7]. However, the complete transection of the hypoglossal nerve results in paralysis and atrophy of ipsilateral tongue [8]. To overcome this deficit, several modifications of the hypoglossal-facial nerve anastomosis have been described [9–11]. The hypoglossal-facial nerve interpositional jump graft, wherein the hypoglossal nerve is cut in transverse direction for 30% to 50% and a graft is interpositioned end-to-end to the peripheral facial nerve, is the most applied of these modifications [12–14].

Depending on the location of the lesion, delay between injury and repair, extent of nerve resection, prognosis, age, wishes of the patient, and several other factors, the surgeon has to select the optimal surgical method, often a combination of several measures, in the individual situation [15,16]. Of course, all these factors also contribute to the functional outcome. In general, it is believed that the earliest possible repair, optimally within 1 month after injury, will result in the best functional outcome of all surgical rehabilitation techniques [4]. Some authors believe that nerve regeneration is slower and the functional results are poorer in older patients [17]. Unfortunately, there is a lack of objective data on the influencing factors and on the outcome after different methods of nerve repair. Because of the rarity of facial nerve reconstructions in many centers, most series of patients with

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facial nerve repair are small, and evaluation of the outcome often is not standardized. Therefore, the objective of this study was to analyze the functional outcome of the mimic musculature after different types of facial nerve reanimation in consideration of electrophysiological data gained by regular postoperative electromyography of the mimic musculature.

Material and Methods

A retrospective study was conducted. We reviewed the case records of all patients who underwent facial nerve repair at a single center (Clinic of Otolaryngology, Head and Neck Surgery, University of Cologne, Cologne, Germany) from December 1993 to December 2003. This time frame was selected to provide adequate follow-up. Only patients with reconstruction of the total facial fan, a follow-up of at least 1 year, and more than 2 electromyography follow-up examinations were included. As a general rule, facial nerve reconstruction was only conducted in patients with a facial paralysis persistent not longer than 3 years.

Five different types of facial nerve reconstructions were differentiated: direct facial-facial nerve anastomosis, facial nerve interpositional graft (1–5 grafts), classical hypoglossal-facial nerve anastomosis, hypoglossal-facial nerve interpositional jump graft, and the combined approach. The techniques and indications are described in detail elsewhere [7,14,18]. In all cases of hypoglossal-facial nerve interpositional jump graft, May's original technique was used [9]. In patients who underwent a combined approach, the upper division was reconstructed with interpositional graft and the lower division with hypoglossal-facial anastomosis or hypoglossal-facial nerve interpositional jump.

A facial-facial nerve anastomosis was chosen in 3 patients with a short interval between lesion and repair and a short lesion that allowed a tensionless end-to-end suture of the nerve stumps. An interpositional graft was selected in 4 patients who showed also a short preoperative facial paralysis interval, but tensionless reconstruction was not possible. In another 12 patients, this type of reconstruction was chosen because of a longer segmental defect in the peripheral facial fan. The indications for hypoglossal-facial nerve anastomosis and hypoglossal-facial interpositional jump graft were principally the same, but the former was the method of choice before (the later after 1998). One of these cross-nerve repair techniques was selected in 20 cases because the interval between lesion and repair was longer than 12 months. In 7 cases, a cross-nerve anastomosis with the hypoglossal nerve was performed because the central facial nerve was not available. A hypoglossal nerve deficit occurred in all patients who underwent the classical hypoglossal-facial nerve anastomosis, whereas after the interpositional jump technique a deficit was only seen in 1 patient. Finally, a combined approach was necessary in 7 patients with extreme defects of the peripheral facial fan where an exclusive reconstruction by nerve grafts was not sufficient to bridge all nerve branches. Irrespective of the chosen reconstruction technique, upper lid loading by gold or a titanium weight was performed in 19 patients for reanimation of eye closure [19]. This procedure bridges the time until the reinnervation of the orbicularis oculi muscle is established. In such a situation, the weight could be removed easily with low morbidity [20].

The patients were examined every 3 months after nerve repair until no further improvement of facial function could be observed. The face was examined at rest, and the function of 6 facial muscles was analyzed: the frontalis, orbicularis oculi, major zygomatic, orbicularis oris, levator labii superior, and the depressor anguli oris muscle. Posttreatment movement of these muscles was assessed using a 7-point visual analog scale (VAS) ranging from 0 points (no function) to 3 points (normal function) in 0.5 steps. Because 6 muscles were evaluated, a maximal overall score of 18 points was possible. Additionally, the final facial nerve function was reported using the May facial nerve grading scale [4,18]. This grading scale was especially designed for reporting of results after facial nerve reconstructions. Briefly, 5 grades from grade I (superb) to grade V (failure) are differentiated depending on the tone and symmetry at rest, at motion, and on the quality of the mimetic movements.

Moreover, at all visits, the facial nerve function was analyzed objectively by electromyography of the same 6 muscles as described previously. Electromyography allows an accurate and early detection of the onset of the recovery of facial function. Typically, it anticipates the visible onset of the facial function [21]. Electromyography with bipolar needle electrodes is a standard investigation tool in routine clinical use in the ENT Department in Cologne [22,23]. The examinations were performed with a Neuroscreen plus system (Jaeger-Toennies, Inc, Hoechberg, Germany). The recordings were analyzed for spontaneous fibrillation potentials, the degree of voluntary polyphasic reinnervation potentials, and synkinetic activity. The recording techniques were published in detail recently [24].

Statistical analysis of the data was performed using SPSS software for medical statistics (SPSS, Chicago, IL). Data are presented as mean ± standard deviation. Differences between to the categorized parameters were analyzed with an analysis of variance followed by a post hoc Bonferroni test. The Pearson's correlation was used to analyze the linear relationship between postoperative time course and clinical function of the facial nerve. All reported P values are 2 sided. A P value $<.05$ was considered to indicate statistic significance.

Results

Patient population

Fifty-three patients (25 females and 28 males) met the inclusion criteria. Their ages ranged from 7 to 78 years, with

Table 1
Etiology of facial paralysis and chosen facial nerve reconstruction (n = 53)

	FFA	Graft	HFA	HFJA	CA	Total
Parotid cancer		11	10	4	6	31
Vestibular schwannoma			5	3		8
Trauma	2	1	1			4
Ear disease		2	1			3
Miscellaneous	1	2	3		1	7

FFA = facial-facial nerve anastomosis; HFA = hypoglossal-facial nerve anastomosis; HFJA = hypoglossal-facial nerve interpositional jump grafts; CA = combined approach.

a mean age of 45.9 ± 17.5 years. Three facial-facial nerve anastomoses, 16 facial nerve interpositional grafts (13 with greater auricular nerve and 3 with sural nerve), 20 classical hypoglossal-facial nerve anastomoses, 7 hypoglossal-facial nerve interpositional jump grafts, and 7 combined approaches were performed. The causes of facial paralysis in relation to the chosen types of reconstruction are summarized in Table 1. Twenty-nine patients were operated on the left and 24 on the right facial side. The interval between the onset of the facial paralysis and reconstructive operation ranged from 0 to 29.4 months (mean, 5.6 ± 8.3 months). Related to the typical indications (Table 1), the time of preoperative facial paresis was significantly longer in cases of hypoglossal-facial nerve anastomosis or hypoglossal-facial nerve interpositional jump graft (9-10 months) than after facial nerve interpositional grafts (1 month; Table 2).

Clinical outcome

The follow-up time ranged from 12.23 to 202.30 months (average, 35.28 ± 43.88 months). Onset of facial movement ranged from 2.76 to 11.86 months (average, 5.41 ± 1.80 months). The function improved approximately until 1 year after operation and remained stable for another year (Fig. 1). There was a strong positive correlation between the increase of facial function and the time course 3 to 12 months after operation (Pearson's correlation $r = 0.52$, $P < .001$).

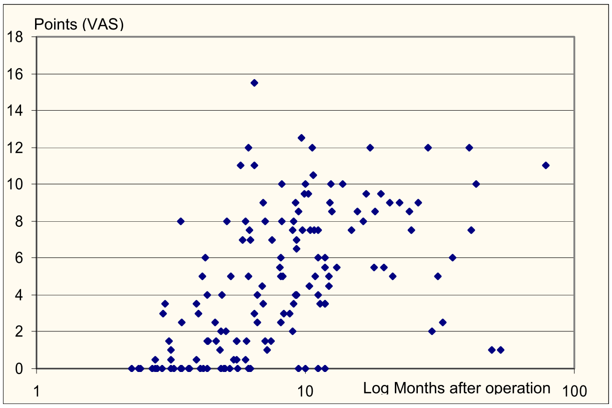

Fig. 1. Time course of rehabilitation of facial nerve function due to the visual grading after operation. Logarithmic x axis (n = 182 measurement in 53 patients).

Finally, the clinical examination (Table 2) using the VAS showed an incomplete reconstitution of the mimic musculature after any type of nerve reconstruction (7.95 ± 2.57 points; ie, 44% of the normal value). The facial reanimation according to the May grading showed a comparable result. Altogether using May's terminology, 7 patients finally showed a superb facial function (grade I, 13%), 18 patients an excellent outcome (grade II, 34%), 15 patient a good result (grade III, 28%), and in 13 patients the result was fair (grade IV, 25%). A poor result (grade V) was not seen. Best results were seen after facial-facial nerve anastomosis (VAS, 11.33 ± 2.08 points; May, 1.33 ± 0.59) and after reconstruction by a combined approach (VAS, 9.92 ± 2.27 points; May, 2.00 ± 0.89). But because of the smallness of the different subgroups, the comparison to the other reconstruction types did not show statistical significance. The functional results after interpositional graft (VAS, 7.69 ± 1.73 points; May, 2.75 ± 0.86), hypoglossal-facial nerve anastomosis (VAS, 7.13 ± 2.90 points; May, 2.94 ± 1.06), and hypoglossal-facial nerve jump graft (VAS, 7.17 ± 2.29 points; May, 2.00 ± 0.89) were equivalent. A comparison of the 6 analyzed facial muscles showed that the functional outcome for the frontalis muscle was significantly poorer than for the other mimic muscles (Table 3).

Table 2
Clinical comparison of different types of facial nerve reconstruction (n = 53)

Type of operation	Preoperative facial paralysis (mo)	Final clinical outcome (VAS) (points)	%†	Final grading outcome (May grading)
Facial-facial nerve anastomosis	0.06 ± 0.10	11.33 ± 2.08	61	1.33 ± 0.59
Facial nerve interpositional graft	1.18 ± 2.11*	7.69 ± 1.73	43	2.75 ± 0.86
Hypoglossal-facial nerve anastomosis	9.37 ± 10.23*	7.13 ± 2.90	40	2.94 ± 1.06
Hypoglossal-facial nerve jump graft	11.61 ± 9.15*	7.17 ± 2.29	40	3.00 ± 0.89
Combined approach	1.62 ± 2.02	9.92 ± 2.27	55	2.00 ± 0.89
Overall	5.64 ± 8.34	7.95 ± 2.57	44	2.66 ± 1.01

* Significant difference ($P < .05$) between nerve graft and hypoglossal-facial nerve anastomosis or hypoglossal-facial nerve jump graft.
† Percent of normal value.

Table 3
Comparison of the final clinical outcome for different facial muscles (n = 53)

Muscle	Final clinical outcome (VAS) (points)
Frontalis muscle	0.42 ± 0.61*
Orbicularis oculi muscle	1.55 ± 0.59
Zygomatic major muscle	1.34 ± 0.54
Orbicularis oris muscle	1.62 ± 0.60
Levator labii superior muscle	1.43 ± 0.60
Depressor anguli oris muscle	1.61 ± 0.60
Overall	7.95 ± 2.57

* Significant lower ($P < .05$) than the other facial muscles.

Electrophysiological examinations

The onset of voluntary activity in the electromyographic analysis was not different between the different types of facial reanimation (average, 4.52 ± 1.31 months; Table 4). Overall, initial regeneration potentials could be detected by electromyography about 1 month before the first facial movements could be seen. Typically, already at the next visit, synkinetic activity could be detected by electromyography (average: 5.01 ± 1.29 months). In contrast, the extent of synkinetic movements of the muscles could be definitely evaluated by clinical examination until 1 year after operation. The regenerative process was overlapped by the degenerative alterations of the distal facial nerve as a result of its Wallerian degeneration. Spontaneous activity as a sign of peripheral nerve degeneration was measured until 7.63 ± 3.91 months after operation. The electrophysiological data were not different between the various types of nerve reconstruction. The time of the onset of voluntary activity did not influence the final clinical outcome; earlier onset did not result in a significant better final nerve function (Table 5).

Analysis of influencing factors

Examination of the relationship between the time of repair and outcome did not reveal that the time of preoperative facial paralysis ranging from 0 to 29.4 months influences the outcome (Table 6). The etiology of the facial paralysis also did not influence significantly the outcome. However, an age of over 60 years resulted in a significant poorer outcome. The time between injury and repair, the etiology, and the age did not influence the time of onset of voluntary activity shown by electromyography.

Comments

In the current series, the selection of the optimal type of facial nerve repair out of 5 possibilities mainly depended on the location of the injury, the etiology, and the duration of the facial paralysis. Using such a standardized strategy in a single institution, the functional outcome was not significantly different between direct nerve repair, autograft repair, facial nerve substitution by the hypoglossal nerve, or a combination of these techniques. As in the recent literature, our data suggest that direct facial-facial nerve anastomosis yields to faster regeneration and better results [3,4]. But, as in other series, either the analysis did not reach statistical significance or a statistic analysis was not performed probably because of the small size of each subgroup [3,4,25].

However, in the present series, it became clearly evident that facial nerve grafting is not superior to cross-nerve substitution by the hypoglossal nerve. This supports our approach to recommend a substitution by the hypoglossal nerve in any case with a preoperative facial paralysis longer than 12 months or in patients in whom the viability of the central facial nerve stump is doubtful. The duration of paralysis is of eminent importance for the selection of the best reanimation: Even when a direct nerve repair is possible in a patient with delayed nerve repair, there is a marked decline in outcome for direct nerve repair later than 3 months after injury [4].

The functional results after hypoglossal-facial interpositional jump graft were equivalent to reconstructions by classical hypoglossal-facial nerve anastomosis. Some authors speculate that using May's jump technique leads to reduced reinnervation but on the other hand to less synkinesis than classical hypoglossal-facial nerve anastomosis [13,14]. We cannot confirm either one of them: the comparison of mimic function and the degree of synkinetic activity were not different. Our results confirm May's original observations [9]. But after classical hypoglossal-facial nerve anastomosis, the patients often complain of dysphagia

Table 4
Electrophysiological comparison of different types of facial nerve reconstruction (n = 53)

Type of operation	Onset of voluntary activity (mo)	Onset of synkinetic activity (mo)	Last spontaneous activity (mo)
Facial-facial nerve anastomosis	3.55 ± 2.00	4.37 ± 1.98	6.00 ± 1.00
Facial nerve interpositional graft	4.92 ± 1.04	5.64 ± 1.30	8.50 ± 5.10
Hypoglossal-facial nerve anastomosis	4.55 ± 1.08	4.99 ± 0.86	5.45 ± 2.91
Hypoglossal-facial nerve jump grafts	4.47 ± 2.08	4.15 ± 1.75	9.69 ± 1.01
Combined approach	4.26 ± 1.20	4.77 ± 1.49	9.40 ± 2.21
Overall	4.52 ± 1.31	5.01 ± 1.29	7.63 ± 3.91

Table 5
Influence of onset of voluntary EMG activity on final clinical outcome

	n	Final clinical outcome (VAS) (points)	%*	Final grading outcome (May grading)
Onset of voluntary activity (months)				
≤2 (very fast)	2	12.50 ± 1.06	69	1.50 ± 0.70
>2–4 (fast)	17	7.00 ± 2.51	39	3.00 ± 0.95
>4–6 (medium)	26	7.55 ± 2.57	42	2.78 ± 0.98
>6 (delayed)	8	9.50 ± 2.21	53	2.00 ± 0.89
Overall	53	7.95 ± 2.57	44	2.66 ± 1.01

EMG = electromyography.
* Percent of normal value.

and speech problems because of the ipsilateral tongue atrophy [26]. Hence, we believe that nowadays the jump technique has left behind the classical approach in most situations.

After reconstruction, first facial movements appeared on average after 5½ months. Data about the onset is only given in a single previous report but only for hypoglossal-facial nerve anastomosis. The results are in accordance with the present data [27]. Interestingly, the onset of visible mimic function in our series was not dependent on the timing of nerve repair. But, again, our general strategy for the indication and selection of the reanimation technique has to be taken into account. In most patients, the paralysis time was not longer than 1 year. Afterward, the outcome is not foreseeable because the mimic musculature becomes more and more atrophic and its fibrosis becomes irreversible. In these cases, dynamic muscle plasties or static procedures to reanimate the paralyzed face have to be recommended [16,28,29]. Looking on the time course of reinnervation, the other important result is that in most cases the regeneration is completed within 12 months after surgery (ie, about 7 months after the onset of first movements). We conclude that in fact the final result of facial reanimation surgery could not be evaluated before this period. Others even recommend waiting 24 months to determine the final result [9].

The recovery of the frontal muscle was significantly poorer than of the other mimic muscles. This phenomenon was also observed in another study [14]. Electromyography often shows sufficient reinnervation of the frontal muscle but also synkinetic activity between the frontal and the orbicularis oculi muscle. These muscles are antagonists. The synchronous activity of both muscles might lead to a clinical autoparalysis [30].

In the present study, age was the most important factor influencing the functional outcome. There was a significant poorer outcome in patients older than 60 years. The influence of age often was postulated [17] but clearly shown for the first time in the present series.

Table 6
Analysis of factors influencing the outcome after facial nerve repair

Factor	n	Final clinical outcome (VAS) (points)	%†	Final grading outcome (May grading)	Onset of voluntary activity (mo)
Preoperative facial paralysis (mo)					
0	16	7.87 ± 2.94	44	2.73 ± 1.22	4.25 ± 1.41
>0–6	18	8.59 ± 2.51	48	2.35 ± 0.86	4.78 ± 1.24
>6–12	4	7.17 ± 0.58	40	3.00 ± 0	5.04 ± 0.18
>12–24	12	7.35 ± 2.75	41	2.90 ± 1.10	4.35 ± 1.57
>24	3	7.25 ± 2.75	40	3.00 ± 0	4.49 ± 0.68
Etiology					
Parotid cancer	31	7.71 ± 2.43	43	2.79 ± 0.98	4.56 ± 1.19
Vestibular schwannoma	8	6.93 ± 2.64	39	2.86 ± 0.90	4.89 ± 1.58
Trauma	4	11.50 ± 1.80	64	1.33 ± 0.58	3.45 ± 2.04
Ear disease	3	7.83 ± 2.08	44	3.00 ± 1.00	5.19 ± 1.23
Miscellaneous	7	8.03 ± 2.60	45	2.00 ± 0.89	4.51 ± 1.24
Age (years)					
≤20	3	10.25 ± 2.47	57	1.50 ± 0.71	5.77 ± 0.37
>20–40	19	8.78 ± 2.54	49	2.43 ± 0.96	4.00 ± 1.63
>40–60	17	8.46 ± 2.28	47	2.38 ± 0.96	4.83 ± 1.45
>60	14	6.00 ± 1.99*	33	3.41 ± 0.67*	4.67 ± 1.26
Overall	53	7.95 ± 2.57	44	2.66 ± 1.01	4.52 ± 1.31

* Significant different ($P < .05$) to other subgroups.
† Percent of normal value.

An ideal and internationally accepted grading system for evaluation of facial reanimation techniques still has to be defined. Often, the popular House-Brackmann scale [31] is used, although it was not designed for facial nerve surgery. This system allows no sensitive discrimination of the degree of emotional movements and the severity of synkinesis. Therefore, we decided to apply May's facial nerve grading system especially designed for the evaluation of facial nerve function after reconstructive surgery [9]. In order to take into account regional differences in the face and to overcome the subjectivity of the system, we used in parallel a simple and reliable VAS system and objective electromyography measurements [32].

Additionally, electromyography could be used to monitor the recovery after nerve repair because it anticipates the clinical functions [33]. In the present series, regeneration potentials could be detected on average already 4.5 months after operation (ie, 1 month before the patient showed any clinical movements). Hence, the success of the nerve repair could be detected earlier than by simple clinical follow-up. Otherwise, if no regeneration potentials are detected after 9 to 12 months after operation, the nerve repair has failed and a decision about revision surgery has to be made. Interestingly, electromyography showed that synkinetic activity is nearly detectable at the same time as the first regeneration potentials. This strengthens the hypothesis that, if we want to overcome synkinesis causally, it will be necessary to manipulate nerve regeneration directly at the moment of nerve repair [29].

Synkinesis is an unpleasant sequelae in any patient after facial nerve surgery. The underlying mechanism is misdirection of the regenerating facial nerve fibers leading to abnormal involuntary associated facial movements [34]. We observed synkinesis in all patients independent of the chosen facial nerve reconstruction technique. Therefore, in any case, the surgeon has to inform the patients about this sequelae and possible therapy before performing the surgery. Mostly disturbing is the blinking while eating or speaking. In these cases, we offer the patients a selective chemodenervation of the affected area by botulinum toxin [35]. Alternatively, selective neurolysis, myectomy, biofeedback rehabilitation, or a special physiotherapy therapy could be offered [36–39].

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