Reestablishment of facial nerve function using hypoglossal-facial anastomosis: clinical outcomes and evaluation of segmented facial performance
ABSTRACT

Objective: To assess the ability to smile following hypoglossal-facial nerve transfer (N12-N7).

Design: Retrospective chart review.

Setting: National tertiary referral center for skull base pathology.

Participants: Seventeen patients

Main outcome measures: The ability to smile following N12-N7 transfer was assessed by five medical doctors on photos of the whole face and frontal, orbital and oral segments. The (segmented) photos were scored: symmetrical, asymmetrical, correct or incorrect assessment of affected side.

Results: Seventeen patients were analysed by 5 assessors providing 85 assessments. The whole face in rest was judged symmetrical in 26% of the cases, and mildly asymmetrical in 56%. Frontal, orbital, and oral segments were symmetrical in 63, 20 and 35% respectively. The affected side was correctly identified in 76%. When smiling, the whole face was symmetrical in 6% and mildly asymmetric in 59%. The affected side was correctly identified in 94%. The frontal, orbital, and oral segments during smiling were symmetrical in 67, 15 and 6%, respectively. The affected side of the frontal, orbital and buccal facial segments during smiling was correctly identified in 89, 89 and 96%, respectively. Interobserver variability with Fleiss Kappa analysis showed that the strength of agreement during smile of the total face was good (0.771).

Conclusions: Following N12-N7 transfer a good facial symmetry in rest can be achieved. During smiling, almost all patients showed asymmetry of the face which was predominantly determined by orbital and oral segments. To improve the ability to smile after N12-N7 transfer additional procedures are needed.

INTRODUCTION

Facial paralysis caused by facial nerve (N7) lesion due to trauma or surgery is a devastating condition which may result in a lifelong loss of function of muscles in the frontal, orbital and oral segments affecting the ability to frown, and close the eye and mouth. In addition, the quality of life is diminished by the loss of the ability to express emotion through smiling [1-4].

In the past decades different techniques for facial nerve reconstruction have been proposed [3,5-10]. One of these is the hypoglossal-facial nerve (N7-N12) transfer, of which numerous technical modifications have been described [10]. One of them is the partial (hemi) use of the hypoglossal nerve with direct end to side coaptation to reduce hemiatrophy of the tongue and diminish recovery time [2,9,11-13].

Over the years, many systems to grade the facial nerve function have been developed [14,15]. Historically, the House-Brackmann (H-B) score is the most well-known and widely used grading system to score facial nerve function, using both characteristics in rest and in motion [16]. Although originally not developed to score facial function after reconstruction and despite its shortcomings, the H-B grading system is also frequently used in studies reporting on outcome of the N7-N12 transfer, namely in around 70% [17]. The H-B grading does not clearly differentiate between the function of different segments of the face in rest and in an active phase. Therefore, detailed information about potential differences between the function in a static or dynamic phase, for instance smiling, is limited [14]. We know that a good smile means increased intelligence, happiness and social status. Therefore, smiling is fundamental in facial reanimation [4].

In this study we evaluate our results of facial reconstruction using the N7-N12 transfer and specifically focus on the ability to smile. Five medical doctors blinded for the side of the N7-N12 transfer independently assessed photos of the whole face in rest and during smiling. Additionally, photos were divided in three segments (frontal, orbital and oral) to determine to what extent it is possible to generate a smile following N7-N12 transfer.

MATERIAL AND METHODS

Patients

In this retrospective cohort study, patients who underwent N7-N12 nerve transfer between 2001 and 2019 were included. Sixteen patients had a N7 lesion following skull base surgery, 1 patient after cholesteatoma surgery (mastoidectomy). We consider the N7-N12 nerve transfer as the best first step in facial reanimation in this situation.
as it potentially reinnervates all muscles of the face. Clinical data were collected from medical records, including the cause of the facial nerve function loss, interval of facial paralysis before surgical reconstruction, outcome of H-B grading and complications during reconstruction.

Patients were excluded when: a) the follow-up was less than 1-year; b) the facial nerve deficit occurred following resections of malignant tumours; c) post-operative photos were unavailable; d) major static procedures were additionally performed (e.g., forehead lift).

Digital photos of the entire face were made by a clinical photographer, and if not present, they were provided by the patients following instructions. Patients were asked to keep the face in rest and to smile to the best of their ability as they would normally do. The photos of the entire face were digitally divided in three segments: frontal, orbital and oral (figure 1). The boundaries of the orbital segment were just cranial and caudal to the supra- and infraorbital margins covering the area of the orbicularis oculi muscle. The frontal segment was the part cranial to the orbital segment, the oral segment was the part caudal to the orbital segment.

Figure 1. Example of photographs and segments, in rest a and b, in active phase c and d.

All the segmented photos during rest and smile were mixed at random and separated from those of the entire face.

The photos were assessed by five medical doctors individually (2 neurosurgeons, 2 ENT surgeons and 1 ENT resident) who were blinded for the side of the N12-N7 transfer. First, the segmented photos were assessed, and one week later those of the entire face. The assessors were asked to indicate whether the face was symmetrical or asymmetrical and if asymmetrical to identify the affected side. If the face was asymmetrical, they had to score whether it was mildly or severely disfiguring. The identification of the affected side was compared to the clinical data, and defined as correct or incorrect.

This study was evaluated by the medical ethics committee of the LUMC. The committee judged that medical ethical review was not required because of the retrospective nature, and patients were not subjected to any procedures and/or behavioural restriction.

Surgical technique of N12-N7 transfer
The surgical technique which was applied was extensively described previously. In short, the extratemporal portion of the facial nerve was identified via a parotid incision, using the posterior belly of the digastric muscle and tragal pointer. The vertical part of the facial canal in the mastoid bone was unroofed. The intra-temporal part of the facial nerve was mobilized and transected at the external facial nerve (2nd) genu. The hypoglossal nerve was identified at the level of carotid bifurcation and neurolyzed as proximally as possible. The hypoglossal nerve was partially cut such that the exposed area corresponded to the cross-sectional area of the facial nerve. A tensionless end-to-side coaptation between the two nerves was made using 10.0 sutures and glue.

Statistical analysis
Statistical analysis was performed using Graph pad Prism (version 9). The assessments in which the affected side was correctly identified were tested using Fisher’s exact test for the comparison between the assessments of the total face in rest compared to active phase (smiling). For the segmented assessments this was done with the Chi square test. The hypothesis was that the observer can identify the affected side more accurately in a smiling patient. The interobserver variability was scored using the Fleiss Kappa analysis in IBM SPSS Statistics version 28.0.1.0. The following strength of agreement was used; <0.20 poor, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 good and 0.81-1.00 very good. Pre- and post-operative H-B grading was tested for significance. A p-value of <0.05 was considered significant.

RESULTS
The study comprised of 11 females and 6 male patients with a mean age 43.5 years at the time of the facial paralysis (SD ±17.7, range 8-68, median 44, Table 1). All patients had a facial paralysis following surgery for VS (n=12), facial schwannoma (n=2), hemangioma (n=1), epidermoid cyst (n=1) and cholesteatoma (n=1, Figure 2a). The average interval between the facial paralysis and reconstructive surgery was 5.2 months (SD ±4.6, range 0-15, median 4). The four patients with preserved facial nerve continuity during VS resection had a longer interval (average 10 months) as compared to the overall average, reflecting the time that passed to assess whether potential spontaneous recovery would
occur. Two patients had surgery and/or facial nerve reconstructions elsewhere (no. 3, 5) and were reconstructed late (>12 months). In one of these patients (no. 5) initially an end-to-end coaptation of the facial nerve was performed and in second instance the N7-N12 transfer was performed. All patients scored H-B VI prior to the N12-N7 transfer. No complications occurred following N12-N7 surgery. The HB grading was performed during outpatient visits with a mean post-nerve transfer interval of 62.5 months (SD ±49.8, range 17-172, median 40). Post-operatively, 13 patients improved to HB grade III (76%), one patient to grade IV (6%), one to grade V (6%) and in two patients the facial function did not recover, with a persisting grade VI (12%) (Table 1, Figure 2b). Patients 3 and 5, which were reconstructed late had a post H-B grade VI (#3) and H-B grade IV (#5). Of the two facial schwannoma patients, one had post-operative H-B grade V and one grade VI. A gold weight was inserted in the upper eyelid of the affected side to improve closure in three patients. Tarsorrhaphies where performed in three patients. Four patients had synkinesis which was treated with botulinum toxin. None of the patients perceived function loss of the tongue.

### Table 1. Results and patient characteristics of the patients who underwent a hypoglossal facial nerve transfer.

<table>
<thead>
<tr>
<th>Patient no</th>
<th>Age</th>
<th>Gender</th>
<th>Pathology</th>
<th>Pre-operative HB</th>
<th>Post-operative HB</th>
<th>Interval lesion-surgery (mo)</th>
<th>FU (mo)</th>
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<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>F</td>
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<td>3</td>
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<td>F</td>
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<td>3</td>
<td>4</td>
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<tr>
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<td>4</td>
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<tr>
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<td>94</td>
</tr>
</tbody>
</table>

FU: routine follow up in months, VS; vestibular schwannoma, FS; Facial schwannoma, H-B; House-Brackmann, F; female, M; male, * neuropraxia, # gold weight eyelid, $ tarsorrhaphy, ‘ Botulinum toxin injections

Postoperative photos were made with a mean interval of of 93 months after N12-N7 reconstruction (SD ±67.3, range 12-212, median 108). In total, 85 assessments of photos in rest and during smile were performed. For the frontal, orbital and oral segments, 255 assessments (17 patients, 3 segments, 5 accessors) both in rest and during smile were performed.

The results of the photo analyses are shown in figure 3, table 2, 3 and 4. The total face in rest was symmetrical in 22 of 85 (26 %). The affected side was significantly less well identified in rest as compared to during smiling (48/63 vs 75/80, p=0.003, Figure 3a). Asymmetry (n=63) was judged as mildly disfiguring in 48/63 (76%) of the patients. When smiling, the asymmetry was scored as severely disfiguring in 30/80 (38%), which was 15/63 (24%) in the rest phase.

In the analysis of the segments, the oral segment during smiling scored asymmetrical in 80 of 85 (94%). In the rest phase, the oral segment was scored symmetrical in 30 of 85 (35%). The affected side in the oral segment during smiling was correctly identified in 77 (96%). The frontal segment was scored symmetrical in rest in 54 (64%) and during smiling 57 (67%). The orbital segment during smiling scored asymmetrical in 72/85 (85%). In the rest phase, the orbital segment scored symmetrical in 17/85 (20%). There was a significant difference (p=0.012) between the orbital and oral segments regarding symmetry in rest and during smiling (Table 4). The identification of the affected side in the active phase in all three segments differed significantly from the rest phase (p<0.0001, Figure 3b).
The results of the interobserver variability using the Fleiss Kappa analysis showed that the strength of agreement during smile was good in the total face (0.771) and in the oral segment (0.641) and moderate in the orbital segment (0.420, Table 5).

**Table 2.** Symmetry assessment of the entire face in rest and during smile (active) following hypoglossal to facial nerve transfer. (n=85) Correct identification of the affected side was only scored with asymmetry.

<table>
<thead>
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<th></th>
<th>Symmetry</th>
<th>Asymmetry</th>
<th>Correct identification</th>
</tr>
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<tr>
<td>Rest</td>
<td>22 (26%)</td>
<td>63 (74%)</td>
<td>48 (76%)</td>
</tr>
<tr>
<td>Active</td>
<td>5 (6%)</td>
<td>80 (94%)</td>
<td>75 (94%)</td>
</tr>
</tbody>
</table>

**Table 3.** Symmetry and level of disfigurement in photo analysis of the entire face following hypoglossal to facial nerve transfer, in rest and during smile (active). (n=85)

<table>
<thead>
<tr>
<th></th>
<th>Symmetry</th>
<th>Mild</th>
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<tbody>
<tr>
<td>Rest</td>
<td>22 (26%)</td>
<td>48 (56%)</td>
<td>15 (18%)</td>
</tr>
<tr>
<td>Active</td>
<td>5 (6%)</td>
<td>50 (59%)</td>
<td>30 (35%)</td>
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**DISCUSSION**

The N12-N7 transfer is widely used to treat the sequelae of a facial nerve lesion. However, not much is known about the functional recovery of facial muscles. This is due to the fact that the grading systems that have been applied in the reports on outcome of the N12-N7 transfer do not clearly differentiate between the face in rest and during an active phase, such as smiling. In this study we found that during smiling, professionals could correctly assess the affected side in more than 90% of cases. There was a 20% increase of asymmetry between rest and smile which was mainly caused by the oral segment of the face and to a lesser extent by the orbital region. These findings suggest that application of additional dynamic procedures to improve the oral segment may be a logical first step to improve smiling after N12-N7 transfer.
The affected side with the face in rest was correctly identified in only 76%. Apparently, it was not evident to distinguish which side of the face was normal and which was reinnervated by the N12-N7 transfer. This might indicate that the appearance of what was mistakenly perceived as the unaffected side, but actually was the N12-N7 reinnervated side, cannot be grossly abnormal. However, the N12-N7 results in a combination of flaccid paralysis components mixed with synkinesis activity, superimposed on faces that may also demonstrate normal aging phenomena.

In this study we asked patients to smile as they would normally do to the best of their ability. Providing these instructions did not lead to an active smile. Noteworthy, patients can generate a smile following a N12-N7 transfer. In order to do so, they have to consciously and forcefully push the tongue against the hard palate. Thereby, the original motor program of the tongue is used to activate the facial muscles. Apparently, the central program to activate a spontaneous smile does not activate hypoglossal motoneurons, which would require central plastic changes to occur 20.

The insufficient activity of the oral segment after N12-N7 transfer may be improved by additional static or dynamic techniques 4,7,8,10. One option that we currently use is to combine the N12-N7 transfer with a transfer of the masseteric nerve branch (N5, trigeminal nerve) to the oral branch of the facial nerve. A N5-N7 transfer alone does not provide symmetry in rest as good as the N12-N7. Therefore a combination might prove optimal 17. To create a smile after N5-N7 transfer, however, one has to close the jaw. Although this is also different from spontaneous smiling, this action comes closer to a natural smile. Additionally, clenching the teeth to smile is easier to perform than pushing the tongue against the palate.

Cross facial nerve grafting is another option to reanimate the facial musculature. If the facial musculature is withered it is one of the very few options, but should be accompanied with gracilis muscle transfer to regain dynamic function. This technique provides a positive trend in disease specific quality of life 21. However, the cross facial technique is complex and requires multiple surgeries of which each has failure rates. These factors have to be weighted in determining what type of treatment is probably the best and they should be discussed with the patients in order to achieve optimal shared decision making.

In a previous study of our group, we reported the outcome of N7-12 transfer procedures using the H-B grading system. In that study, 86% of the patients had a H-B grade III in contrast to 76% in the present study 2. The difference can be explained by the fact that in our earlier report, patients with facial schwannomas were excluded. Facial schwannoma causes a slowly progressing paralysis, which usually takes years to develop. Irreversible atrophy of a part of the facial musculature occurs over time, excluding muscle fibres for reinnervation by a nerve transfer which thereby causes a negative impact on outcome 22-24. If we would have excluded the patients with a facial schwannoma, the overall H-B grade III score in the remaining series increases to 87%, which is comparable with earlier reports 6,11. Optimally, facial reinnervation following a complete injury right from the start is performed within 6 months after the onset 14. Since the process of facial nerve function deterioration is a gradual process in case of a facial nerve schwannoma, patient counselling with regard to the timing of nerve transfer is key for good outcome.

The weaknesses of this study are the relatively small number of patients, the fact that intra-observer variability was not assessed and the retrospective nature of the study. The strength is that the outcome was independently performed by 5 assessors. In addition, the method of segmental analysis of the reconstructed (N12-7) face provides deeper insight in the contribution of the frontal, orbital and oral parts of the face to obtain symmetry and the generation of a smile. In our opinion, this study, using (segmented) photographs and observer assessments is unique. Other studies concerning facial reanimation and post operative results, use different scoring systems which are categorized in observational, mathematical and computer-graphical measurements 14. Nevertheless, this study addresses the question if a N7-N12 transfer generates a good smile observed by five medical assessors.

CONCLUSION

Following a N7-N12 transfer, the majority of patients obtain a good symmetry of the face in rest, but they cannot generate a natural smile. Both static and dynamic analysis of the facial nerve innervated muscle function is not only essential to adequately evaluate outcome of facial nerve reconstructions, but also provides clues which additional dynamic procedures may be required to improve overall outcome.
REFERENCES


