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Revascularized muscle transfer for facial reanimation after long-standing facial paralysis

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Abstract. The aim of the present study was to evaluate the results of a group of patients who had received free vascularized muscle transfer to the face for the treatment of long-standing facial paralysis. In 15 patients, neurovascular transfer of 16 segments of the gracilis muscle to the cheek was performed for reanimation of oral commissure movement. Voluntary muscle activation was evaluated by electromyography (EMG) and clinical function was assessed both metrically from frontal photographs and by a rating system with 6 categories. Patient satisfaction was explored through a self-administered questionnaire of general health (SF-36 health survey). The average follow-up period was 49.3 months. All patients showed voluntary activation of the grafted muscles in the EMG. Symmetry of the static and dynamic position of the oral commissure at rest and under function was considerably improved. In general, however, there was a tendency for undercorrection particularly in a vertical direction. Under function, the excursion of the oral commissure on the grafted side reached 63.7% and 65.5% of the nonparetic side in vertical and horizontal directions, respectively. Subjective rating of patient well-being showed that the scores were higher than or comparable to those of healthy adults in six of eight areas of evaluation.

Key words: facial reanimation; facial nerve palsy; muscle grafts; microsurgery.

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Long-standing facial paralysis results in denervation atrophy of the muscles of facial expression. In order to repair long-standing facial palsy, nerve grafts alone are unsuccessful if the reconstruction is performed after a period of more than 6 months following interruption of the motor nerve supply[17,19], as motor end plates have degenerated and the muscle tissue has undergone fibrous transformation. To compensate for the atrophy of the facial muscles and to provide movement to the facial soft tissues, the concept of free revascularized muscle grafts for facial reanimation was developed experimentally and clinically in the late seventies and has been widely introduced into clinical practice of reconstructive surgery in the recent decade[9,12,16,20,21]. It is therefore the aim of the present study to evaluate the experiences with neurovascular transfer of the gracilis muscle to the face for restoration of dynamic movement of the oral commissure.

Material and methods

Between 1991 and 1998, sixteen gracilis muscle grafts were transferred to the face as free neurovascular muscle segments for reanimation of movement of the oral commissure after long-standing facial paralysis in 15 patients (8 women, 7 men, mean age: 31.2 years (6–59 yrs)). In 10 patients, damage to the facial nerve resulted from tumor resection such as neuromas of the acoustic nerve and parotid gland tumors. In two patients, there was a congenital defect of the facial nerve function owing to Moebius' syndrome and in three cases, traumatic injury to the facial nerve by a skull base fracture had resulted in facial paralysis.

In three cases, paralysis was incomplete, in that the nerve supply to the periocular muscles was still functioning, while the innervation of the orbicularis oris and levator muscles was interrupted. In the remaining patients, facial paralysis was complete. The mean time for which paralysis had been present was 7.3 years (4–12 yrs).

Surgical procedure

In all patients, the oral commissure was approached above the superficial muscular aponeurotic system (SMAS) with wide exposure of the cheek (Fig. 1b). In one patient, simultaneous resection of a recurrent lymphangioma was performed (Fig. 1a). A segment

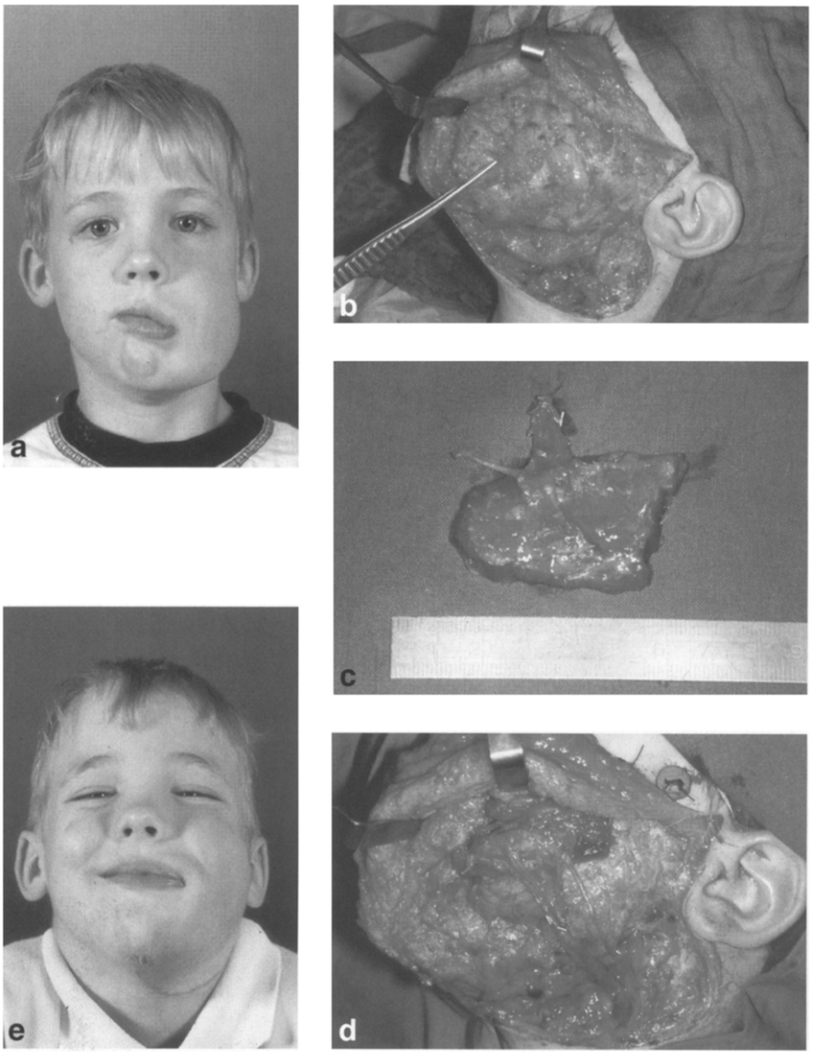

Fig. 1. a. Extraoral appearance of a 6-year-old boy with paralysis of the lower third of the face due to a previously operated lymphangioma. b. Dissection of the skin to the oral commissure for adequate surgical exposure. Lymphangioma not yet resected. c. Segment of the gracilis muscle with the vascular pedicle and the branch of the obturator nerve. d. Fixation of the muscle around the oral commissure after tumor resection, securement of the position of the angle by buried stay sutures. Vascular anastomoses done with the retromolar vein and the maxillary artery. Nerve coaptation with the descending ramus of the hypoglossal nerve, that had been transposed to the cheek. e. Appearance 6 weeks postoperatively. Improved symmetry already by the static function of the muscle graft.

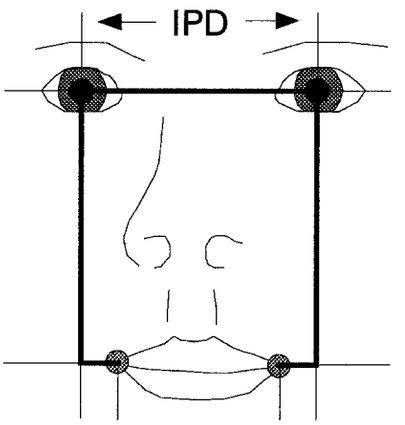

Fig. 2. Schematic drawing of the metric evaluation of commissure position from frontal photographs. All measurements were expressed as percentage of the interpupillary distance (IPD), to neutralize different magnifications. The position of the commissure was defined as the distance to the interpupillary line and to a line perpendicular to it through the pupils.

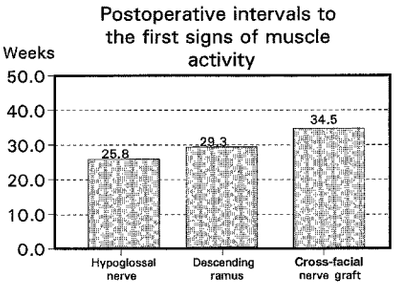

Fig. 3. Postoperative interval with the first signs of muscular activity.

from the gracilis muscle of approximately 7×3 cm was harvested with the vascular supply through the adductor branches arising from the profunda femoris artery and vein and nerve supply through the anterior branch of the obturator nerve (Fig. 1c). The volume of the muscle was reduced under constant nerve testing by longitudinal resection of muscle fibers in order to avoid bulking during function later on. In cases where there still appeared to be too much muscle volume, the buccal fat pad was thinned out to accommodate the belly of the grafted muscle. At its one end, the muscle graft was divided into three parts which were sutured to the upper lip, the labial commissure and the lower lip, respectively. The opposite end of the graft was fixed to the epiperiosteal tissue overlying the malar bone (Fig. 1d), so that the tension of the graft was able to hold the position of the commissure after 3–4 weeks (Fig. 1e). Buried stay sutures were placed between the lips and the malar skin to hold the position during healing of the muscle. Blood flow was re-established by anastomosis of the flap vessels with the facial artery and vein in 14 grafts, the facial artery and the jugular vein in 1 patient and the maxillary artery and retromandibular vein in 1 patient. Nerve coaptation with the anterior branch of the obturator nerve was performed using a part of the hypoglossal nerve, which had been dissected under the microscope ($n=7$), the descending ramus of the hypoglossal nerve ($n=6$) and a cross-facial nerve graft from the sural nerve that had been placed 10 months before ($n=3$). Four to six weeks postoperatively, transcutaneous electrical stimulation of the grafted muscle was started to avoid muscle atrophy during nerve regeneration.

Follow-up evaluation

Eleven of the 15 patients were available for the retrospective evaluation. Two patients had died in the meantime and two patients refused to come to the examination. The mean postoperative interval was 49.3 months (13–97 mo).

Patients were evaluated for four different parameters:

i) Voluntary activation of the grafted muscle was examined through electromyography (EMG).

ii) Excursions of the oral commissure were assessed metrically similar to a system suggested by JOHNSON et al.[1,11] Horizontal and vertical movements of the commissure point were measured on frontal photographs in resting and smiling mouth position (Fig. 2). The distances were normalized to the interpupillary distance (IPD) to account for differences in magnifications of the individual pictures. Orthogonal lines through the interpupillary line served as reference lines.

iii) Assessment of the overall results was performed in 6 categories according to HARII et al.[10]

Grade 5: Symmetric balance and good facial tone at rest. Sufficient muscle power during voluntary contraction. EMG demonstrating high amplitudes and full interference pattern.

Grade 4: Symmetric balance and good facial tone at rest. Active muscle contraction acquired but not sufficiently synchronous.

Grade 3: Acceptable symmetric balance and facial tone at rest. Insufficient contraction of the muscle. Low action potentials in the EMG.

Grade 2: Reduced symmetric balance upon rest. No effective contraction of the muscle. EMG without interference patterns.

Grade 1: No correction. Electrically silent EMG.

Grade 0: No follow-up.

iv) Estimation of patient health-related well-being and life quality using the SF-36 health survey questionnaire[24]. This self-administered questionnaire contains 36 items and assesses life quality and patient health according to eight categories:

1) physical function, 2) role limitations due to physical problems, 3) social functioning, 4) role limitations due to emotional problems, 5) general mental health, 6) bodily pain, 7) vitality and 8) general health perception. Scores for each category range from 0 to 100. The German translation of the questionnaire was used for the present study[5]. The results were compared to those known from previously evaluated populations of healthy adults[5].

Results

All muscle grafts took well and no vascular complications were encountered which would have required revision of the anastomoses. Six patients underwent additional surgery for debulking of the muscle graft after a mean period of 32.3 months (11–47 mo). In two patients, gold weights were implanted into the upper eyelid to facilitate lid closure.

The first signs of muscle activity were noticed at an average postoperative interval of 30.5 weeks (9–39 wks). This interval was shortest in those grafts whose motor nerve supply was accomplished through coaptation with the split hypoglossal nerve (25.8 weeks), while the first appreciable activity of the muscle occurred later in patients in whom the branch of the obturator nerve was connected to the descending ramus of the hypoglossal nerve (29.3 weeks) or to the cross-facial grafts (34.5 weeks) (Fig. 3). This difference, however, was not significant in an ANOVA (P=0.7485).

Electromyographically, all patients showed voluntary activation of the grafted muscle. Amplitude and duration of the action potentials were variable. In three patients, there were signs

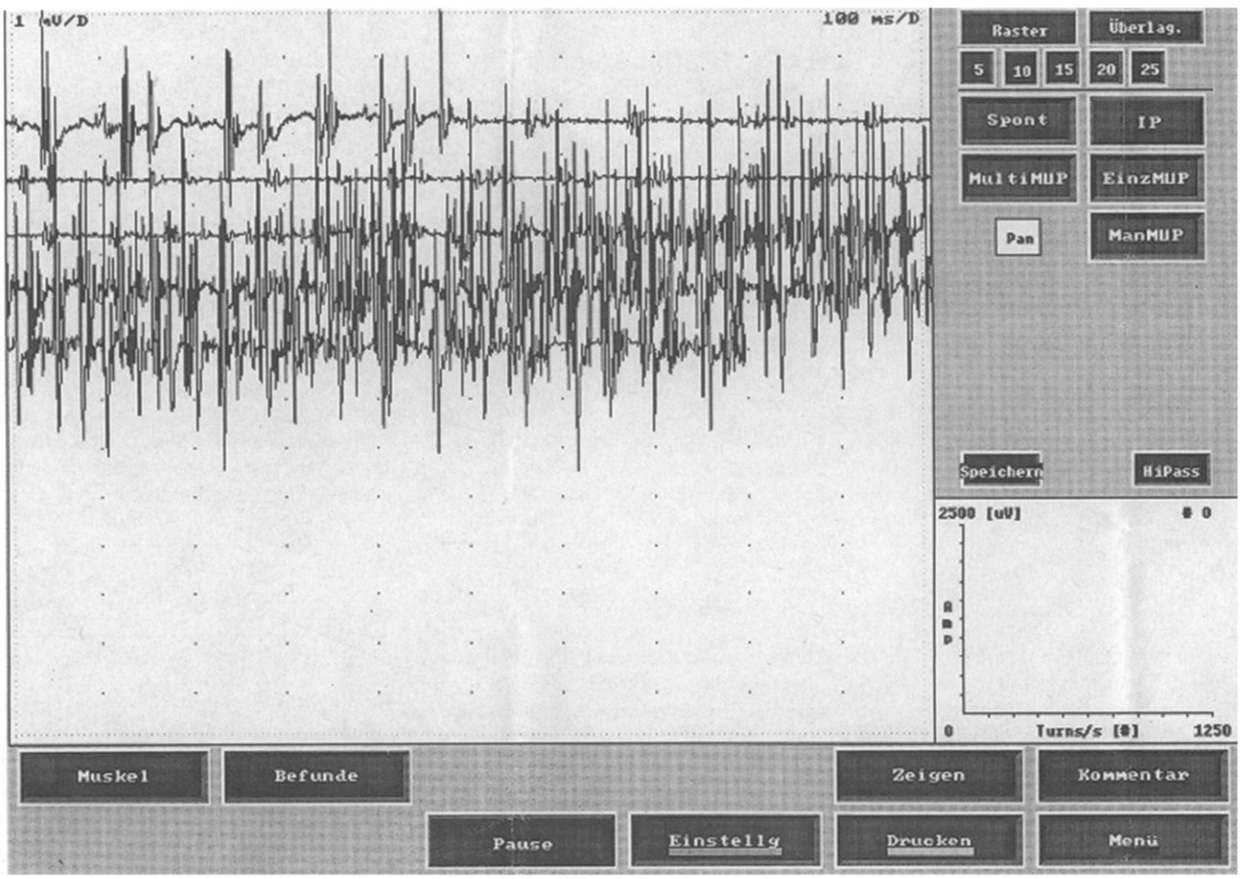

Fig. 4. Electromyography of a muscle graft with a large number of activated motor units.

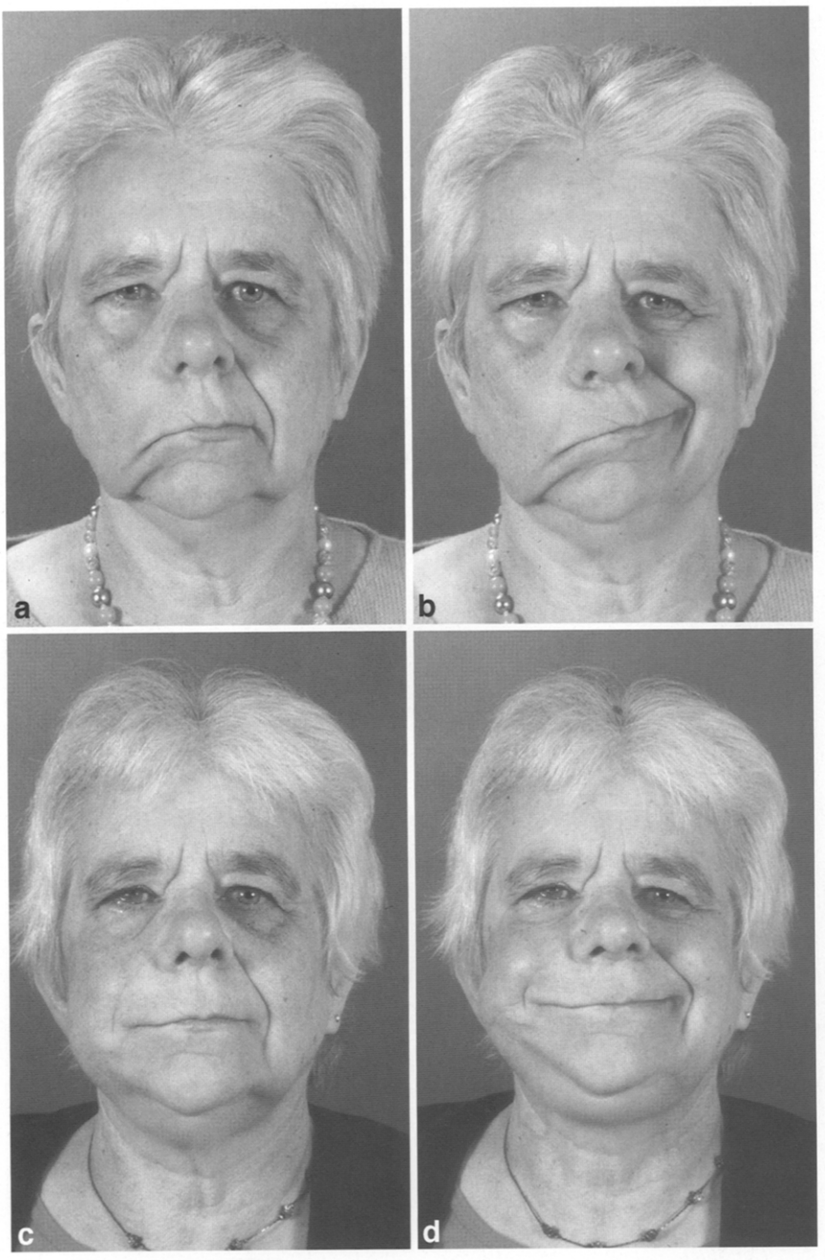

Fig. 5. a. 59-year-old patient 4 years after removal of an neurinoma of the acoustic nerve. Severe asymmetry. b. The same patient preoperatively smiling with elevation and lateralization of the oral commissure on the non-paretic side. c. The same patient 3 years postoperatively; improved facial symmetry at rest. d. The same patient with considerably improved function during smiling.

of chronic neurogenic damage to the muscle but clear voluntary activity. In the remaining patients, there were considerable numbers of voluntarily activated motor units indicating a good graft function (Fig. 4).

On clinical examination, all patients exhibited clearly visible contraction of the muscle and movement of the labial commissure. Figs. 5a and b show a patient 4 years after resection of a neuroma of the acoustic nerve, with complete facial nerve palsy and ptosis of the facial soft tissues on the right hand side. Three years after transfer of a revascularized neuromuscular graft from the gracilis muscle, there was considerable improvement in facial symmetry at rest and during smiling (Figs. 5c and d).

Metric evaluation showed that the static position of the labial commissure had been elevated by 58.2% and placed laterally by 66.1% of the distance required for perfect symmetry by the grafting procedure. In comparison with the non-paretic side, the position of the oral commissure was positioned 3.3% of the interpupillary distance (IPD) lower and 4.2% more medial (Fig. 6). Movement during smiling occurred in a direction that was very similar to that of the non-paretic side of the face. On average, the extent of the formerly paretic commissure reached 63.7% and 65.5% of the non-paretic side in vertical and horizontal directions, respectively (Fig. 7), which resulted in a position of the commissure that was 8.2% of the IPD lower and 2.4% more medial than the opposite commissure. The static position of the philtrum was displaced laterally towards the non-paretic side by 4.2% of the IPD, but moved closer to the midline during smiling (2.4% of the IPD).

The overall results were categorized as grade 5 only in one case, while 6 patients were rated grade 4 owing to a slightly weaker movement of the commissure on the paretic side. Four patients achieved grade 3 due to low activity in the EMG (Fig. 8). Three of the four patients with grade 3 had undergone secondary surgery for debulking of the muscle graft.

The assessment of the health-related quality of life by the SF-36 health survey exhibited comparable values on average for every category when compared to the values of a group of healthy adults reported previously[3]. In categories such as physical functioning and general health perception, the score was clearly reduced compared to the reference population while in others such as pain, social function and role limitation due to emotional problems, there were even higher values than the reference groups (Fig. 9).

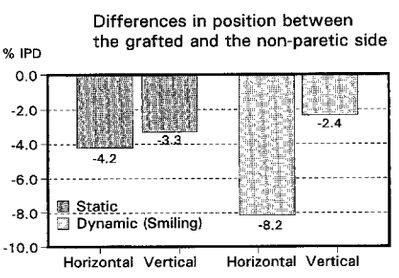

Fig. 6. Position of the oral commissure on the grafted side in relation to the non-paretic side.

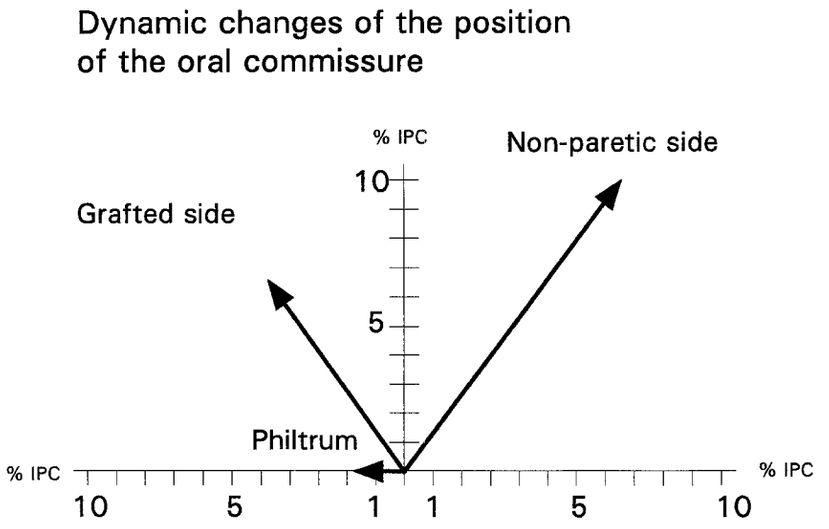

Fig. 7. Dynamic changes of the oral commissure during smiling.

Discussion

The concept of free neurovascular muscle transplantation for the treatment of facial paralysis has undergone several modifications since its introduction by HARII et al.[9] in 1976. In particular, the two-stage technique with the use of a cross-facial nerve graft has prompted the development of several approaches using a one-stage reconstruction. One way to avoid a two-stage procedure has been the use of muscle grafts with a long motor nerve supply that allows for direct connection to the contralateral facial nerve. KOSHIMA et al.[13,14] have used the transfer of the rectus abdominis muscle with the motor branch of the intercostal nerve and the rectus femoris muscle with its long motor nerve emerging from the femoral nerve. HARII et al.[10] have suggested the latissimus dorsi muscle with the thoracodorsal nerve for one-stage reconstruction. An alternative way of providing direct nerve supply has been the use of a different source of motor nerve. UEDA et al. have used the hypoglossal nerve for direct connection to the grafted muscle. They recommended the use of the lower section of the nerve which supplies the suprahyoid muscles[22,23]. In the present study, the one-stage approach by direct connection to the hypoglossal nerve and its decending ramus has been preferred. The clinical results with both nerve coaptations were satisfactory. However, the hazard of tongue dysfunction after microdissection of the hypoglossal nerve and the necessity to trace the nerve into the tongue muscles make the descending ramus appear to be preferable for its easy dissection and convenient length.

Another problem of the free transfer of muscle segments to the face is the fact that the adequate muscle volume is difficult to determine. On the one hand, it is important for esthetic reasons to avoid deformity by the occurrence of muscle bulk during function. ERNI et al.[5] have described the swelling of the cheek during activation of the grafted muscle to be one of the esthetic drawbacks of the microneurovascular transfer that tends to counteract the improved functional result in subjective assessments. On the other hand, it is known that a change in muscle innervation can result in morphologic alterations[8,25]. Therefore, overdimensioning of the muscle during transplantation has been recommended[6] and, in a large study population, 26% of the patients underwent revision and debulking of the free muscle graft[21]. However, in the present study, three of the six patients who had secondary surgery for muscle volume reduction, had reduced numbers of action potentials in the EMG with reduced amplitude, indicating fibrotic changes of the muscle tissue. Thus it appears from the present results, that trimming of muscle volume should be performed as far as possible during muscle transplantation to avoid secondary revision of the muscle and the hazard of scar formation and fibrotic changes.

The extent and the vector of movement of the oral commissure are the most critical points when considering the functional and esthetic results of free muscle grafting for reanimation of facial movement. The use of frontal photographs to assess this vector can only provide two-dimensional information and thereby can incompletely reflect the angular movement. It has been stated that the further lateral the commissure moves, the more relevant the third dimension becomes with the posterior movement of the angle[15]. However, as measurements were used to compare the changes on an intra-individual basis, the mode of assessment used in the present study may be con-

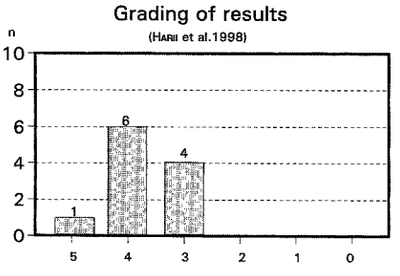

Fig. 8. Results according to the grading system of HARII et al.[10] Grade 5: Symmetric balance and good facial tone at rest. Sufficient muscle power. Grade 4: Symmetric balance and good facial tone at rest. Active muscle contraction not sufficiently synchronous. Grade 3: Acceptable symmetric balance and facial tone at rest. Insufficient contraction of the muscle. Grade 2: Reduced symmetric balance upon rest. No effective contraction of the muscle. Grade 1: No correction. Electrically silent EMG. Grade 0: No follow-up.

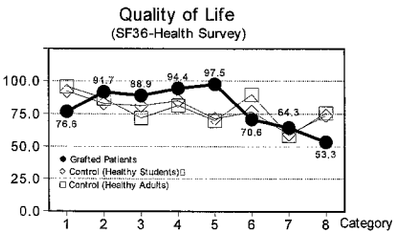

Fig. 9. Results from the SF-36 health survey questionnaire. 1) physical function, 2) role limitations due to physical problems, 3) social functioning, 4) role limitations due to emotional problems, 5) general mental health, 6) bodily pain, 7) vitality and 8) general health perception.

sidered as valid for comparison of pre- and postoperative pictures. Furthermore, the values obtained compare favourably with those of ERNI et al., who used a three-dimensional measuring device[5]. Nevertheless, it must be borne in mind that the results only represent relative values.

The angle of the commissure movement and the re-creation of a nasolabial fold are determined during transplantation by the direction in which the muscle graft is fixed. In this respect, it has to be taken into account that there can be considerable differences in the structure of the nasolabial fold, caused by variable compositions of midfacial muscles[18]. The risorius muscle, for instance, has been identified in only 6% of the dissected midfacial soft tissues, while the zygomaticus minor muscle has been still present in 34%. The individual variability in occurrence and in thickness of the midfacial muscles thus requires meticulous analysis of facial movement before determining a vector of movement for the grafted muscle. The plane of insertion of the muscle to the skin also plays an important role. When the nasolabial fold is to be recreated, the insertion of the transferred muscle should be placed underneath the cheek fat pad toward the deep surface of the upper lip[7].

Finally, facial expression is never due to one muscle acting alone and an ideal result of facial reanimation surgery is supposed to provide balanced constrictor and dilator forces. In order to do so, it will be necessary to produce vector pulls upwards, downwards and laterally[4]. However, even a separation of the grafted muscle end into three parts with fixation in the upper and lower lip and the commissure can only produce one common vector of movement, as the three divided "subheads" cannot be activated separately. This makes it difficult to achieve a perfectly symmetric smile in a patient who shows a lot of his teeth during smiling. In this case, the levator muscles are very active during smiling and would have to be substituted by a muscle strain which is able to elevate not only the commissure but also the upper lip, by constructing a vector that points to the infraorbital rim. However, this is impossible to achieve with only one muscle graft, and secondary corrections may become necessary[21]. The metric evaluation has revealed a certain degree of asymmetry in each patient, which was not quite consistent with the grading of the overall results. This is accounted for by the fact that the symmetry of facial appearance particularly during function results not only from the extent and the vector of movement of the oral commissure, but also from the changes of facial soft tissues during movement, in particular the nasolabial crease. Furthermore, as the human face is known to be asymmetric to a certain extent, metric evaluation may not perfectly reflect the clinical appearance. In patients with a very satisfactory clinical result (such as shown in Fig. 5a–d), the metric evaluation had shown a divergent position of the oral commissure of −2.7% of the IPD in vertical and −9.7% in horizontal directions.

The assessment of life quality as an indicator for patient satisfaction has been performed in the present study by using the SF-36 health survey. This questionnaire was constructed by WARE et al. in 1992. It was developed to address general health concepts not specific for any age, disease or treatment group in a short-form scale to avoid the use of lengthy instruments otherwise used as general health measures[24]. The SF-36 health survey had been previously validated in a German-speaking version, in both fairly large reference populations of healthy subjects as well as patients with chronic non-malignant diseases[3], and had also been used for self-assessment in a recent report on cleft lip and palate patients[2]. It therefore appeared to be suitable for indirect evaluation of subjective estimation of treatment results in the present study, as direct questions as to whether the patients were satisfied with the result and whether they would have this procedure done again may have been subject to some kind of bias by the social desirability of the answer. The results have shown, however, that the patient self-assessment was quite comparable to that of healthy adults. Although physical function was judged slightly lower than in the reference population of BULLINGER et al.[3], it is remarkable that physical role, emotional role function, social function and psychological well-being were rated considerably higher. This may reflect a high degree of satisfaction in that patients apparently feel well-integrated into their social life and environment.

In conclusion, the present study has shown that the free neurovascular transfer of segments from the gracilis muscle for facial reanimation in long-standing facial paralysis has resulted in improvement of facial symmetry in terms of position and movement of the oral commissure, although the extent of movement of the commissure has been smaller than that of the non-paretic side in metric evaluations. Problems associated with the procedure are the calculation of the graft volume and the fact that the upper lip cannot move separately from the commissure. This makes perfect symmetry difficult to achieve in certain patients.

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