Video Article

Single-stage Dynamic Reanimation of the Smile in Irreversible Facial Paralysis by Free Functional Muscle Transfer

Jan Thiele[1], Holger Bannasch[1], G. Bjoern Stark[1], Steffen U. Eisenhardt[1]

[1]Department of Plastic and Hand Surgery, University of Freiburg Medical Centre

Correspondence to: Jan Thiele at jan.thiele@uniklinik-freiburg.de

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Abstract

Unilateral facial paralysis is a common disease that is associated with significant functional, aesthetic and psychological issues. Though idiopathic facial paralysis (Bell's palsy) is the most common diagnosis, patients can also present with a history of physical trauma, infectious disease, tumor, or iatrogenic facial paralysis. Early repair within one year of injury can be achieved by direct nerve repair, cross-face nerve grafting or regional nerve transfer. It is due to muscle atrophy that in long lasting facial paralysis complex reconstructive methods have to be applied. Instead of one single procedure, different surgical approaches have to be considered to alleviate the various components of the paralysis.

The reconstruction of a spontaneous dynamic smile with a symmetric resting tone is a crucial factor to overcome the functional deficits and the social handicap that are associated with facial paralysis. Although numerous surgical techniques have been described, a two-stage approach with an initial cross-facial nerve grafting followed by a free functional muscle transfer is most frequently applied. In selected patients however, a single-stage reconstruction using the motor nerve to the masseter as donor nerve is superior to a two-stage repair. The gracilis muscle is most commonly used for reconstruction, as it presents with a constant anatomy, a simple dissection and minimal donor site morbidity.

Here we demonstrate the pre-operative work-up, the post-operative management, and precisely describe the surgical procedure of single-stage microsurgical reconstruction of the smile by free functional gracilis muscle transfer in a step by step protocol. We further illustrate common pitfalls and provide useful tips which should enable the reader to truly comprehend the procedure. We further discuss indications and limitations of the technique and demonstrate representative results.

Video Link

The video component of this article can be found at http://www.jove.com/video/52386/

Introduction

The facial nerve is involved in ocular protection, articulation, oral continence and greatly affects the aesthetic appearance of the face. Impairment of this nerve is therefore associated with significant morbidity and social withdrawal. Despite significant advances in therapy, the multitude of problems associated with the paralyzed face can only be targeted with a broad spectrum of additional procedures. Common to all surgical techniques is the need for an exact anatomical knowledge.

Facial nerve anatomy

The facial nerve consists of a branchial motor component for voluntary motor control of the facial musculature and a visceral motor component for parasympathetic control of lacrimal, submandibular, and sublingual glands. Besides, there are two sensory components for the innervation of the external auditory canal and for the taste in the anterior two third of the tongue. The course of the facial nerve can be subdivided into three segments: intracranial, intratemporal, and extratemporal. In the intracranial segment, the upper group of neurons that innervate the frontalis muscle and the periauricular region receives bilateral cortical input. Neurons that innervate the remaining facial muscles receive contralateral cortical input exclusively. As a consequence, frontalis function is maintained in ipsilateral supranuclear lesions. The intratemporal segment can be further divided into three segments. In the labyrinthine segment, the greater petrosal nerve leaves the trunk to supply the lacrimal gland with parasympathetic fibers[1].

In the mastoid segment, the thin stapedius nerve runs to the correspondent muscle. Parasympathetic branches innervate the submandibular, sublingual and anterior lingual glands, whereas the anterior two thirds of the tongue are supplied with gustatory fibres (chorda tympani). The main stem of the facial nerve exits the bony canal through the stylomastoid foramen. This is the beginning of the extratemporal segment, however arborisation does not start before entering the parotid gland. The nerve is first divided into 3 to 4 motor divisions that form the intraparotid plexus and ultimately give rise to the temporal, zygomatic, buccal, mandibular and cervical branches[2].

Differential diagnosis of facial paralysis

As etiology of facial paralysis is broad and hard to classify, the division that is affected should be considered first.

Intracranial facial paralysis can be caused by lacunar infarcts or tumors of the intracranial cavity. Bacterial and viral infections, cholesteatoma and Bell's palsy can be reasons for intratemporal nerve damage. Neoplastic malignancies and associated surgical therapy are the dominant causes for extratemporal facial paralysis. Although Bell's palsy represents the most common diagnosis in patients with facial paralysis, most patients recover completely without sequelae and do not need surgery[3]. The second most common cause of facial paralysis is trauma. Here, fractures to the temporal bone are the predominant trauma mechanism[4].

Treatment types of facial paralysis

Numerous surgical options exist for the treatment of facial paralysis and they may be classified into reinnervation, static reconstruction and dynamic reconstruction. Typically, two years are considered to be the time from injury in which function after reinnervation can be regained satisfactory with reinnervating procedures[5]. Later on, denervation atrophy of facial muscles precludes their usefulness for further reconstruction. Reinnervation can be obtained by primary nerve repair, interpositional nerve grafts, cross-facial nerve grafting or cranial nerve transfer. Static reconstruction techniques are directed to correct functional disabilities, (protection of the cornea, improvement of nasal airflow, and prevention of drooling) and to improve symmetry at rest. Typical procedures are browlift for brow ptosis, or canthoplasty for lower lid ectropion. Static reconstruction is preferred in elderly patients with significant comorbidities or in massive facial defects secondary to trauma or cancer resection.

The surgical techniques of dynamic reconstruction can be subdivided into regional muscle transfer and free microneurovascular muscle transfer with either coaptation to the masseter motor branch or cross-facial nerve grafting. The latter represents the criterion standard for the reconstruction of the smile in facial paralysis, as no other treatment option reliably achieves a spontaneous smile that is crucial to improve social handicap. Coaptation to the masseter motor branch is the treatment modality of choice for patients with bilateral paralysis, however indications have extended, as elderly patients or patients with significant comorbidities usually prefer a single-stage procedure[6].

Gracilis flap

Regional anatomy

The gracilis muscle is a rather superficial muscle of the medial thigh, representing the longest muscle of the adductor muscles. It originates from the lower symphysis and the inferior ramus of the pubis. Running distally, the muscle becomes narrow and inserts distal to the knee joint on the tibia that allows not only adduction of the thigh but also flexion of the knee. The gracilis muscle has a type II circulatory pattern after Mathes and Nahai with an arterial supply from a dominant and some minor vascular pedicles[7]. The dominant artery exits the muscle at the hilum to course laterally and usually terminates in the medial circumflex artery. Rarely, the dominant artery terminates directly in the deep femoral artery. Venous supply of the gracilis muscle is usually achieved through two venae comitantes, that course deep to the adductor longus muscle to follow the dominant artery. Innervation of the muscle is achieved through an anterior branch of the obturator nerve that enters the muscle 1-2 cm superiorly to the hilum.

Clinical use

The gracilis muscle is a valuable donor muscle for reconstructive microsurgery and has become the muscle of choice for many surgeons for functional free muscle transfer. This is owed to the fact that there is little donor site morbidity and the flap shows optimal proportions with regards to excursion of the muscle and vascular pedicle dimensions respectively. A long single innervated motor nerve alleviates functional flap harvest[8].

We here demonstrate the case of a 49 year old female, who initially presented with a complete picture of left peripheral facial paralysis following resection of an acoustic neuroma (vestibular schwannoma) 2 years earlier. The patient was most afflicted by facial asymmetry, particularly when smiling. Other pre-existing comorbidities were not documented.

Upon clinical examination, the patient showed a complete paresis of the frontalis muscle, however a satisfactory forehead symmetry at rest. Lid closure was insufficient on the left with a lagophthalmos of 5 mm and Bell's phenomenon. Signs of cornea irritation and ectropion were absent. At rest, the patient showed a moderate asymmetry of the corner of the mouth with a tragus-modiolus distance of 11 cm on the right and 11.5 cm on the left at rest. Upon smiling, tragus-modiolus distance scaled down to 9 cm on the right and elongated on the left to 12 cm. After extensive counseling, the patient wished for a single-staged dynamic reconstruction of the smile with a free functional gracilis transfer using the masseter as donor nerve. The patient was also informed about various techniques of lid closure reconstruction, however declined surgical treatment at this stage. The course of the treatment was uncomplicated. Signs of reinnervation were first noticed three month postoperatively. Four months after surgery, the patient presented with unremarkable scarring along the former modified facelift incision line. Symmetry at rest and deliberate smiling were excellent with a satisfactory definition of the nasolabial crease. The patient also showed a completely spontaneous smile. Pre- and 9-month postoperative range of excursion of the corner of the mouth was documented by videography.

Protocol

NOTE: The Patient shown in the video has agreed on publication of the video material. Written consent was obtained. The protocol follows the guidelines of the human research ethics committee of the University of Freiburg. Though surgeons may have different preferences, the following protocol will focus on the authors' preferred technique.

1. Pre-operative Workup

1. Accomplish a standardized pre-operative work-up that consists of a structured history and thorough examination for accurate treatment planning. Thereby, request the etiology of the disease and ask for functional limitations. It is of utmost importance to determine the time elapsed since onset of the paralysis as this affects planning of treatment.
2. Take a functional history including oral continence, drooling and speech. Ask the patient how s/he is limited in social life due to aesthetic and psychological issues.
3. Next, take a general medical history to rule out any co-morbidity that would affect the surgical plan.
4. Examine the patient from the brow down. Evaluate the degree of brow ptosis, dermatochalasis, lagophthalmos, and ectropion.
5. Check for midface ptosis and for nasolabial crease asymmetry and quantify the excursion of the oral commissure. Note the symmetry of teeth exposure upon smiling and the shape of the smile.
6. Examine the cranial nerve V to establish the availability as donor nerve and palpate the facial and superficial temporal arterial pulses to help determine their availability as recipient vessels. Usually upon biting, palpate the masseteric muscle to indicate a functioning masseteric nerve. If unsure, perform an EMG (electromyography) to rule out any deficits of the masseteric nerve.
7. Finally, take a series of standardized photographs or videography for medical record with the patient's face at rest, upon smiling with mouth open and closed. Include a lateral view as the frontal view alone cannot capture the whole amount of movement.
8. Communicate the treatment options to the patient and closely involve the patient in the decision-making process as this represents the key to a successful outcome.
   NOTE: Here, we will focus on the dynamic reconstruction of the smile in patients who present with irreversible atrophy of the facial musculature that are no candidates for or do not wish a two-stage procedure.
9. Illustrate the risks of the procedure such as flap loss, hematoma formation, infection, pain, scarring, and unsatisfactory post-operative excursion of the oral commissure and acquire informed consent from the patient. Demonstrate postoperative photographs of previous patients as this will give the patient an idea what to expect and how scarring will look like.
10. Perform the operation under general anesthesia without muscle relaxation in order to be able to use a nerve stimulator to identify the masseteric nerve and the obturator branch to the gracilis muscle. Perioperatively, administer a prophylactic antibiotic second-generation cephalosporin (*e.g.*, 1.5 g of Cefuroxime) intravenously.
11. Place the patient supine. Prevent pressure points by using protective padding. Fix the breathing tube to the mandible with an interdental suture (0-0) in order to prevent dislocation from moving the head during surgery.
12. Use the gracilis muscle from the ipsilateral thigh. Apply Povidone-iodine solution (250 ml) to the leg that has been chosen for flap harvest and use Octenidine Hydrochloride (500 ml) for skin and mucosal disinfection of the head and neck.

2. Facial Preparation

NOTE: Perform the procedure with a two team approach. Here, surgical steps are described one after another.

1. Turn the patient's head to the healthy side and adjust the height of the operating table as desired to alleviate subsequent preparation steps. Together with medical binocular loupes, a LED (light-emitting diode) head light lamp is extremely useful for facial dissection.
2. Carefully plug fatty gauze into the auditory canal. This prevents blood from flowing in and coagulating.
   NOTE: Through the application of hairclips, shaving of hear bearing scalp is not necessary.
3. Mark the facial incision line. Begin in the scalp approximately 2 cm cranial to the upper pole of the ear. Then course downward in the preauricular area anteriorly to the tragus. Perform a submandibular extension of the incision line of approximately 1.5 cm for adequate exposure and the controlled placement of sutures along the oral commissure in the course of the operation.
4. Before incision is made, apply suprarenin diluted in normal saline solution subcutaneously (dilution: 1:200,000, 40 ml maximum). This prevents excessive bleeding during dissection. Wait for vasoconstriction that is visible shortly thereafter.
5. Begin dissection at the level of the SMAS (superficial aponeurotic muscular system). At the anterior border of the masseter muscle continue dissection sub-SMAS in order to identify the facial artery and vein. Prevent visual constraints in the operative field by decent hemostasis in using the bipolar cautery.
6. Superiorly, extend the dissection up onto the body of the zygoma and the temple.
7. Locate the temporal vessels that pass superficially over the posterior root of the zygomatic process of the temporal bone, thereby covered by a thin fascia.
   NOTE: In case of failure of the facial vascular dissection, these vessels may serve as rescue vascular supply to the muscle flap.
8. Identify the facial vessels anteriorly to the masseter muscle. Identify the artery by pulsation and the thick aspect of the vascular wall. It first courses anteriorly parallel to the body of the mandible and then curves upwards. At the oral commissure, it divides to give vascular supply to the lower lip.
   1. Locate the vein that, unlike the artery consist of a thin vascular wall, thereby showing a typical blueish aspect. If the vessels are difficult to identify, locate them at the chin where they cross the mandible.
9. Continue dissection anteriorly just above the vessels to the commissure and upper lip. Achieve a long exposure as this is necessary to allow for relocating the vessels towards the masseter muscle for an easy microvascular anastomosis to the pedicle of the gracilis muscle. Try to avoid surgical scissors for preparation of vessels. Use non-traumatic blunt instruments instead.
10. Apply a micro vessel clip to the proximal end of the facial artery and corresponding vein and clip the distal part. Reflect the vessels posteriorly to alleviate subsequent revascularization of the flap.
    NOTE: The following steps are essential for a satisfying postoperative result.
11. Start positioning of the sutures for secure anchorage of the muscle at the modiolus close to the oral commissure. Place sutures in the sinewy material of the atrophied perioral musculature. Use a double armed 3-0 polypropylene suture.
12. Place the second suture in the lower lip so that with traction it will elevate the lower lip.
    NOTE: This suture will serve as an unlocked temporal pull-out suture to relieve the traction from the flap within the first days after surgery and it will be tied over a bolster after flap insert. The pull-out suture does not take a bite of the muscle and will be removed on postoperative day 7. It is lead out in the temporal region as described in step 4.16.

13. Place the third and fourth sutures in the upper lip along the course of the facial artery.
14. Carefully check the placement of the four sutures by equally pulling all sutures. The presence of a harmonic natural looking nasolabial crease together with the absence of eversion or inversion of the skin indicates an agreeable result. In case of lip inversion the sutures are most likely placed too deep, in case of eversion most likely too superficial. Correct by choosing the correct layer placement.
NOTE: Typically, more than one attempt is necessary for optimal positioning. This step is most crucial for the aesthetic outcome of the procedure. Consider that upon smiling, the upper lip shows a remarkable degree of cranial movement indicating the importance of the upper lip sutures.
15. Once satisfied with the position of the suture, cover the very caudal suture for technical facilitation in order to not confuse it with the sutures that will be used for flap fixation. Lock the remaining sutures carefully and leave the needles in place.
16. Locate the masseteric motor nerve. Therefore, define a point 3 cm anterior to the tragus and 1 cm inferior the zygomatic arch[9].
    1. From here, start to locate the nerve that is coated by perineurium and appears with a yellowish aspect. At the posterior margin of the masseteric muscle, the nerve "points" at the oral commissure and forms an angle of 50° with the zygomatic arch. Dissect the masseter bluntly parallel to its fibers using fine scissors and try not to stretch the nerve.

17. For easier access, dissect the origin of the masseter muscle from the zygomatic arch.
18. Next, dissect downward to the undersurface of the muscle. Apply a nerve stimulator as this is extremely helpful to not confuse the nerve with other structures. Use a unipolar electrical probe attached to a stimulator source that allows variable voltage and frequency control.
19. Once identified, trace the nerve into the muscle and remove fibrous connections.
NOTE: The nerve will begin to divide into numerous branches after a 1 cm intramuscular course.
20. Strip the nerve as distal as possible and flip it over to lie at a superficial level for microsurgical coaptation.
NOTE: At this point the face is fully prepared for the muscle transplant.

3. Flap Harvest

NOTE: The gracilis flap is harvested simultaneously with the facial dissection.

1. Before dissection, be aware that gracilis flap harvest for facial reanimation is best achieved in the proximal one-third of the thigh. Focus on this area during dissection.
2. Start with an upper medial thigh skin incision of about 10 cm in length at the anterior border of the gracilis. As a landmark, palpate the tendinous origin of the adductor longus muscle in the medial thigh. Apply monopolar electrodissection to go deep.
NOTE: The saphenous vein is encountered first and preserved by medial retraction.
3. Expose the adductor fascia and identify the adductor longus and gracilis muscle. The gracilis muscle is located posterior to the adductor longus muscle.
4. Once the gracilis muscle is encountered, locate the neurovascular pedicle first so as to preserve it during preparation. Therefore, spread into the thin fascia between the adductor longus and adductor magnus and identify the neurovascular pedicle here. Subsequently, track the pedicle to the hilum on the deep surface of the gracilis.
5. To locate the neurovascular pedicle, define a distance of approximately 8 to 10 cm from the origin of the muscle to distally as this is the region of the hilum. Alternatively, identify the cutaneous perforator of the muscle that also originates from the hilum.
6. Dissect the neurovascular pedicle between the gracilis and adductor longus muscle.
7. Hold the adductor magnus muscle aside and trace the pedicle laterally under the adductor longus muscle.
NOTE: Vascular connections with the adductor longus and brevis are coagulated or ligated, and divided.
8. Dissect the pedicle proximal to the branches to the adductor longus and apply a vascular loop to the very proximal end of the vascular pedicle.
9. Identify the motor nerve to the gracilis which is an anterior branch of the obturator nerve that enters the muscle 1-2 cm superiorly to the hilum. Retract the adductor longus muscle for easy tracing of the nerve to the obturator foramen to provide maximum length.
10. Define the segment to be harvested. Note that the length of the muscle transplant has to be adapted to each patient individually. The distance from the oral commissure to the tragus plus 2 cm will give the length of the muscle transplant[10] as 1 cm on each side of the flap will be needed for flap anchorage.
11. Place the pedicle at the midpoint or slightly distal of the removed muscle segment, as the distal end of the flap will be placed at the oral commissure and the proximal end close to the tragus.
12. Dissect the muscle circumferentially for a distance of at least 2 cm in excess of the length required using surgical scissors.
13. Mark the required muscle segment including the vascular hilum in the middle of the segment. Do not completely dissect the vascular pedicle from the nerve as this may harm the vessels.
14. In order to reduce the muscle bulk, harvest about 30% of the circumference of the muscle. Ideally separate an anterior and posterior muscle segment that is not included with the pedicle. Apply the nerve stimulation to confirm the integrity of the separated segment. Strong contraction should be visible.
15. Carefully divide the vessels at, or near their origin, using micro ligation clips and remove the muscle segment.
16. Achieve hemostasis using the bipolar cautery and irrigate the operative site thoroughly by using sterile saline solution (250 ml).
17. Position a Redon-drain through a stab incision to prevent postoperative hematoma or seroma formation.
18. Close the wound with interrupted resorbable subcutaneous sutures (2-0) and an intracutaneous Polypropylene suture (2-0).
19. For ex vivo preparation of the muscle flap, place the gracilis segment on a separate operating table and thoroughly rinse the artery with diluted heparin solution (4-5 ml, 10 units/ ml) in order to prevent intravascular thrombus formation.
20. Check the motor nerve for integrity by application of the nerve stimulator. Strong contraction of the muscle has to be apparent. Rinse the isolated muscle flap frequently with sterile saline solution to prevent drying out of the tissue.
21. Insert the distal end of the muscle into the nasolabial crease. To prevent rupture, place non-resorbable mattress sutures or alternatively a continuous suture along the distal end (3-0 Polypropylene). These sutures will provide stability for the anchor- sutures.
NOTE: These sutures can also be placed at the temporal end, however are not as crucial as at the oral end of the muscle.

4. Flap Insertion

1. Suture the anchor-sutures that have been placed in the mouth through the muscle in an interlocking fashion so that they overlap the distally placed continuous suture of the muscle.
2. Suture guided, cautiously insert the flap into the facial cavity by two surgeons. Stretch one and arrange the anchor sutures while the other surgeon inserts the flap. Remove the needles afterwards and tie the sutures tightly in order to prevent secondary release.
3. Have the nursing staff move in the operating microscope. Bring the clamped ends of the facial artery and vein in an adequate position for revascularization by using micro scissors.
4. Adjust the pedicle of the gracilis muscle. Usually, anastomose the larger of the two veins to the facial vein under the operating microscope.
5. Place a piece of a penrose drain underneath the vessel ends to increase the contrast and to hold back excessive tissue.
6. Start vascular repair with the artery and carefully bring the vessel ends together.
   NOTE: Stress-free adjustment is indispensable to prevent thrombus formation.
7. Use diluted heparin solution (5 ml; 10 units/ml in saline solution) to flush the lumen of the vessels. This will give an idea of the quality of the intima as endothelial damage will become visible. If necessary, trim back the vessel end to remove damaged endothelium. Remove excessive adventitia meticulously.
8. Use interrupted 9-0 Nylon sutures to adjust the front side of the artery first and then turn the vessel ends 180° to complete the anastomosis on the rear side. Make sure to not penetrate the front and back side with one suture by repeated inspection of the vessel lumen.
9. Continue with the venous anastomosis that can be more demanding. Venous vessel walls are much thinner and, unlike the artery, tend to collapse shortly after rinsing. Use interrupted 9-0 Nylon sutures for the venous anastomosis.
10. Upon release of the clamps pulsation of the artery and venous charge should be visible. In order to check for adequate refill of the vein, use two pairs of microsurgical tweezers to obliterate a section of the vein distal to the anastomosis. Then open the proximal tweezers to observe the rate of recharge in order to exclude false positive retrograde refill.
11. Apply an implantable Doppler probe for monitoring of the flap against the draining vein. Therefore, trim the silicone cuff to fit the probe loosely around the vein. Afterwards, secure the cuff with Nylon sutures (9-0)[11]. Avoid constriction of the vein as this may promote thrombus formation.
12. Lead the Doppler cable out of the wound and connect it with the control box. A smooth venous noise should be audible. In case of arterial pulsation, try to relocate the cuff away from the artery.
13. Turn the attention to the nerve repair. Adjust the length of the motor nerve of the gracilis to the minimum that is required for tension free coaptation. At this stage, extend the muscle to its temporal fixation point to test which neural pedicle length is necessary once the muscle is completely extended. Any excessive length will needlessly extend time to reinnervation.
    1. Use high-power magnification for coaptation with interrupted 9-0 Nylon sutures in epineural fashion. Consecutively apply fibrin glue that will give additional stability to the coaptation site.
14. Close the muscle fascia of the masseter afterwards using absorbable sutures (3-0) in order to deliver some degree of protection to the coaptation site. Avoid suturing the fascia too tight as this may compress the nerve.
15. Following the neurovascular repairs, secure the muscle origin to the temporal fascia and preauricular fascia with mattress sutures (4-0 Polypropylene). Provide sufficient tension with the muscle flap to produce a lateral movement of the oral commissure. This will ensure maximal movement of the oral commissure once reinnervation occurs. If necessary, distribute the muscle evenly to prevent bulking.
16. Divert the pull-out suture at the temporal end of the wound and tie it with sufficient tension over a bolster in order to keep tension off the muscle for the first post-operative week.
17. Check for any bleeding vessels and perform meticulous hemostasis with the bipolar cautery.
18. After thorough irrigation of the operative site, position a silicone drain (Jackson-Pratt) through a stab incision to prevent postoperative hematoma formation that might constrain flap perfusion. Alternatively, use a Penrose drain.
19. Reposition the cheek flap and close the wound with staple sutures in the hair bearing areas and a continuous 5-0 Nylon suture.
20. Before wound closure is completed, apply fibrin glue into the wound cavity for hemostasis and stabilization of the pedicle[12].
21. Fix the Doppler cord with an adhesive bandage and apply antibiotic ointment to the wound. A head bandage may then be applied to cover the preauricular incision area. As the vascular pedicle is located more anteriorly, this will not compromise flap perfusion.

5. Postoperative Treatment and Follow-up

1. Postoperatively, leave the patient in the recovery room for about 4-6 hr and then transfer to the plastic surgery ward. Keep the patient's body in a slightly elevated position to minimize swelling. Mobilization can be initiated on postoperative day one.
2. Provide soft food and prohibit to speak for three days. This prevents loosening of the anchor sutures in the nasolabial crease. Remove the facial drain on postoperative day two and the Redon drain of the medial thigh after output is below 30 ml/24 hr.
3. Brief the nursing staff how to handle the Doppler control box and to control the Doppler signal hourly. In case of impairment of blood flow immediate revision surgery is necessary.
4. As discharge can usually be achieved after 5 days, remove facial stitches together with the pull out suture after 7 days. Remove the Doppler probe by pulling it out of the wound 3 weeks after surgery.
   NOTE: The muscle usually begins to contract within 3 months postoperatively. Patients often report a “funny feeling” in their cheeks, which is soon followed by active movement of the corner of the mouth and a smile.
5. Perform follow-ups 3 and 6 months postoperatively with a thorough examination of the patient. Evaluate the symmetry of oral commissure excursion, symmetry of the cheek volume and identify any synkinesis. Document the presence of a spontaneous smile.
6. Finally, take a series of standardized photographs as described in step 1.7 or videography for medical record.

Representative Results

The use of the masseteric nerve for reinnervation of the muscle graft was assessed in 5 patients (**Table 1**). Among them, acoustic neuroma resection was the main cause for facial paralysis. 3 candidates preferred the single-stage procedure rather than the “gold standard” two-stage approach. In two patients, the procedure served as a rescue procedure after insufficient stimulation by the cross-facial nerve graft (CFNG).

Reinnervation of the gracilis flap after single-stage repair was detectable within 3 months. Oral commissure excursion was satisfactory in all patients (**Figure 1**) however a spontaneous smile could only be achieved in one patient and occasionally in two patients. Secondary thinning of the flap was necessary in three patients.

Representative results are shown within the video.

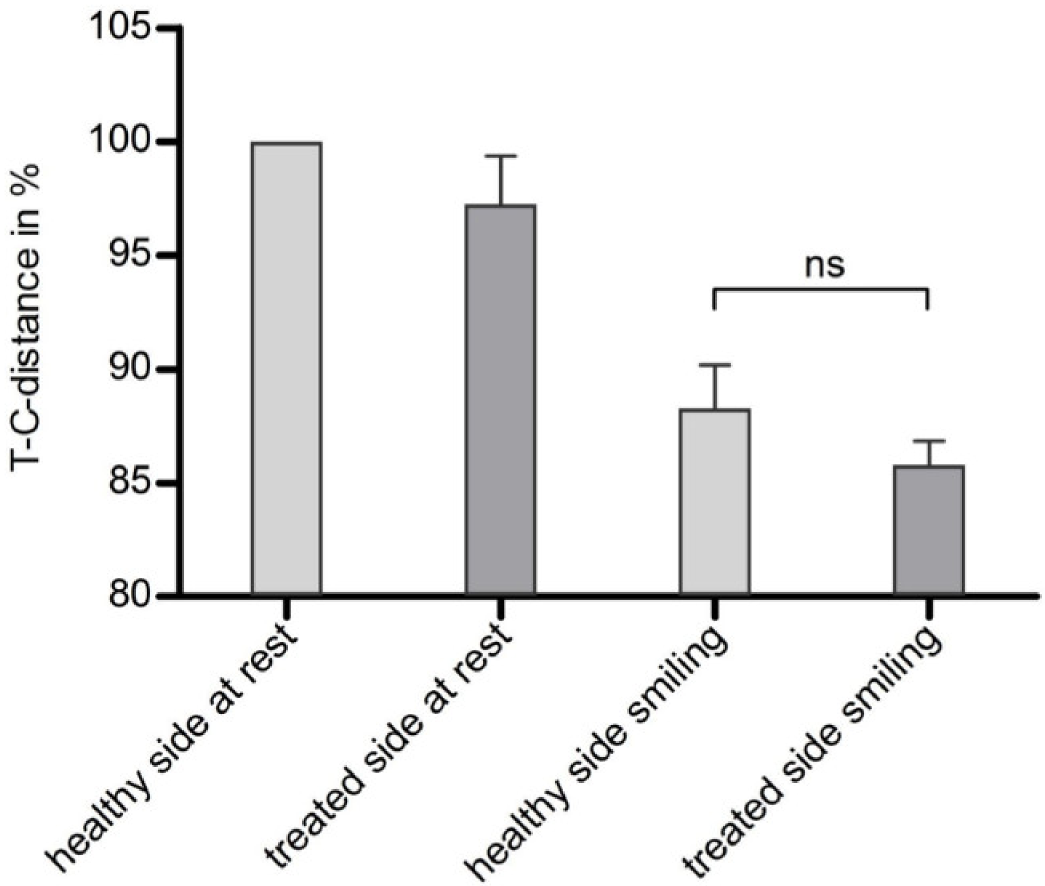

Figure 1: Post-operative evaluation of the distance between the tragus and the oral commissure (T-C) at rest and under maximal excursion of the oral commissure. Values are in % of the healthy side at rest (n = 5). The use of the masseteric nerve for reinnervation of the muscle graft provides a strong excursion of the oral commissure with a symmetrical result when compared to the healthy side (ns= not significant).

Patient	Age	Gender	Cause of palsy	Time of palsy	Indication for masseteric reinnervation	Time to reinnervation	Complications	Follow-up operation	Spontaneous smile
1	44	F	Acustic neuroma resection	4 years	Single-stage procedure	3 months	None	Thinning of the flap	No
2	51	F	Parotid tumor	3 years	Single-stage procedure	3 months	None	Thinning of the flap	No
3	22	F	Acustic neuroma resection	8 years	Insufficient stimulus of the CFNG	3 months	None	Thinning of the flap	Occasionally
4	43	M	Astrocytoma	10 years	Insufficient stimulus of the CFNG	4 months	None	---	Occasionally
5	49	F	Acustic neuroma resection	2 years	Single-stage procedure	3 months	None	---	Regularly

Table 1: Patient demographics.

Discussion

Even though different surgical techniques have been described to regain a dynamic smile in patients with long standing facial paralysis, the two-stage repair with initial cross facial nerve grafting and consecutive free gracilis muscle transfer is seen as the “criterion standard”.

Although a two-stage procedure, the technique allows for spontaneity of the smile which is seen as a crucial factor to overcome the social handicap associated with facial palsy[13].In cases of bilateral facial paralysis and Möbius syndrome, the concept of muscle transplantation in the absence of the seventh nerve can be applied. Here, the masseter nerve as a branch of the trigeminal (fifth nerve) has increasingly been recommended to power the free muscle flap. As elderly patients or patients with significant morbidity tend to prefer a single-stage procedure, indications of the masseteric coaptation have significantly been expanded during the last years[14].

There are clearly several advantages of masserteric nerve grafting. Apart from secondary thinning of the flap that is necessary in some patients, using the masseteric nerve is a single-stage procedure that preserves the contralateral healthy facial nerve and allows for a greater axonal load that is delivered to the flap. Conversely, incomplete reinnervation and partial muscle atrophy is often seen after facial nerve grafting, as less than 50% of axons cross the nerve graft[15,16]. Using the masseteric nerve results in a greater excursion of the oral commissure when compared to coaptation of the neural pedicle of the muscle flap to a cross-face nerve graft and consequently might be the method of choice in patients with a strong contralateral smile where cross-face nerve grafting is insufficient to restore symmetry[14]. Therefore the masseteric nerve can also be used to innervate a gracilis muscle flap in a secondary procedure when a gracilis muscle flap primarily innervated by a CFNG does not show sufficient muscle excursion to achieve a symmetric smile[17]. As a result of the strong neural input and minimal atrophy of the muscle, thinning out of the flap may become necessary in some patients that then require a minor secondary procedure.

In some patients, single-stage reanimation of the smile powered by the masseteric nerve does not provide spontaneous activity. The smile movement must be learned as part of a conscious effort. However, spontaneity can be observed in about two thirds of the cases which is also confirmed by our own observations[18]. To date, the determinants of achieving a spontaneous smile after masseteric reinnervation are unknown, though the parallel innervation of the masseter muscle upon smiling that is seen in about two thirds of the population or alternatively, a degree of cortical plasticity that develops following a program of biofeedback exercises have been proposed[19,20]. Further research is needed to specify the determinants of achieving a spontaneous smile in the future in order to provide the patient with an individualized treatment plan.We believe that once clear predictions can be made on whether the patient will achieve a spontaneous smile with this single stage procedure we might see a change in paradigm regarding reanimation of the face as in these patients a masseteric nerve coaptation could be preferable to a CFNG coaptation.

Crucial to success is the surgery of the recipient vessels and nerve, as well as the meticulous preparation of the gracilis muscle. Even though most plastic surgeons should be familiar with the raising of the gracilis muscle as a free flap the situation in this context is more demanding. The segmental harvest of the muscle is challenging, as the neural supply has to be maintained. When separating the muscle segment the usefulness of a neural stimulator cannot be emphasized enough. The repetitive control during dissection that the harvested segment still responds by contraction to stimulation of the neural pedicle ensures that no intramuscular branches have been dissected. If unexpectedly the gracilis muscle cannot be harvested or does not seem to be suitable for free flap transfer the adductor magnus muscle can be raised instead as a salvage procedure[21].If patients cannot or do not want to undergo microsurgical reconstruction, we usually choose local muscle transfers that can achieve good outcomes but are generally regarded as second choice to free flap transfers[22]. After microsurgical gracilis muscle transfer, we strongly recommend the use of an implantable doppler probe as this allows for a continuous monitoring of flap perfusion. Though controversy exists in the use implantable dopplers, our own data showed a revision success rate of 75 to 90% that proves that the system is efficient enough in daily use[23].

In conclusion dynamic reanimation of the smile remains to be of one of most demanding areas in plastic surgery. Under the multitude of surgical techniques, we here describe pre- and postoperative workup of the single-stage reconstruction utilizing the motor nerve to the masseter and precisely elucidate every single surgical step. We emphasize the importance of a thorough pre-operative patient counseling, as this will significantly affect patient satisfaction. We illustrate the atraumatic preparation of facial vessels and the masseter nerve in a step-by-step fashion. The elevation of the gracilis flap should be a standard procedure to every plastic surgeon. For functional muscle transfer however, there are certain features to be considered in order to gain ideal functional flap dimensions. Finally, we emphasize the importance of flap positioning and application of initial tension for achieving a natural symmetrical smile.

Disclosures

The authors have nothing to disclose.

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