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MULTIMEDIA MANUSCRIPT EXPERIMENTAL/SPECIAL TOPICS

Facial Reanimation Utilizing Combined Orthodromic Temporalis Muscle Flap and End-to-Side Cross-Face Nerve Grafts

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Abstract
Background Individuals with facial paralysis of 6 months or more without evidence of clinical or electromyographic improvement have been successfully reanimated utilizing an orthodromic temporalis transfer in conjunction with end-to-side cross-face nerve grafts. The temporalis muscle insertion is released from the coronoid process of the mandible and sutured to a fascia lata graft that is secured distally to the commissure and paralyzed hemilip. The orthodromic transfer of the temporalis muscle overcomes the concave temporal deformity and zygomatic fullness produced by the turning down of the central third of the muscle (Gillies procedure) while yielding stronger muscle contraction and a more symmetric smile. The muscle flap is combined with cross-face sural nerve grafts utilizing end-to-side neurorrhaphies to import myelinated motor fibers to the paralyzed muscles of facial expression in the midface and perioral region. Cross-face nerve grafting provides the potential for true spontaneous facial motion. We feel that the synergy created by the combination of techniques can perhaps produce a more symmetrical and synchronized smile than either procedure in isolation.
Methods Nineteen patients underwent an orthodromic temporalis muscle flap in conjunction with cross-face (buccal–buccal with end-to-side neurorrhaphy) nerve grafts. To evaluate the symmetry of the smile, we measured the length of the two hemilips (normal and affected) using the CorelDRAW X3 software. Measurements were obtained in the pre- and postoperative period and compared for symmetry.
Results There was significant improvement in smile symmetry in 89.5 % of patients.
Conclusion Orthodromic temporalis muscle transfer in conjunction with cross face nerve grafts creates a synergistic effect frequently producing an aesthetic, symmetric smile.
Level of Evidence V This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors at www.springer.com/00266.

Keywords End-to-side neurorrhaphy · Facial palsy · Reconstructive surgical procedure · Surgical flap grafts · Temporal muscle · Orthodromic

Introduction

Facial paralysis produces significant functional and aesthetic deficits and the associated emotional sequela can

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have a severe negative impact on the individual's social and professional life. Numerous procedures have been developed to treat facial paralysis; however, many are limited by their ability to yield consistent, reproducible symmetry of the mouth at rest and during active smiling. Microsurgical advances, including cross-face nerve grafts combined with regional muscle transfers, have significantly enhanced the ability to reliably deliver a dynamic, natural-appearing result [1–4]. Neurotization of the native muscles of facial expression is a valuable tool in the bid to achieve dynamic reanimation in facial palsy [5].

In patients with facial paralysis of less than 6 months (early group), without evidence of clinical or electroneuromyographic improvement, our center employs cross-face nerve grafts with end-to-side (ETS) neurorrhaphies in an effort to neurotize the individual's facial expression muscles. This is achieved with two sural nerve grafts and ETS neurorrhaphies, creating a transfacial connection between selected buccal and zygomatic facial nerve branches [6].

In patients with facial paralysis longer than 24 months (late group), there is limited potential to achieve meaningful neurotization as a result of irreversible atrophy of the facial expression muscles. In this patient population, orthodromic temporalis muscle flaps have proved to be a reasonably effective technique [7]. The surgery can result in an appropriate smile but it lacks spontaneity. Initially, clenching of the teeth is required to generate the desired temporalis muscle contraction and subsequent smile. Diligent practice in front of a mirror can improve the dynamics of the smile. Over time, children and highly motivated adults can demonstrate brain plasticity and are able to generate a more effortless, reflexive smile without biting [8].

In cases of facial palsy that has lasted between 6 and 24 months without clinical or electroneuromyographic improvement, the combined orthodromic temporalis muscle flap and cross-face nerve grafts with ETS neurorrhaphy has been utilized, yielding a synergistic effect. We present this new combined approach for the surgical rehabilitation of the paralyzed midface and perioral region that has consistently produced a more spontaneous and synchronized smile with good aesthetics.

Fig. 1 The sural nerve is harvested using multiple small incisions

Fig. 2 Temporalis tendon grasped by Kocher's clamp

Patients and Methods

Nineteen patients underwent facial reanimation via the orthodromic temporalis muscle flap in conjunction with cross-face nerve grafts with end-to-side neurorrhaphies (buccal–buccal with end-to-side neurorrhaphies). There were nine male and ten female patients. Ages ranged between 12 and 86 years with an average age of 47.2 years (±20.7). The cause of facial palsy was congenital ($n = 2$), trauma ($n = 5$), infection ($n = 1$), tumor ($n = 7$), and idiopathic ($n = 4$).

The surgery was performed under general anesthesia utilizing a two-team approach. The teams worked simultaneously with one preparing the face while the other harvested the fascia lata and sural nerve grafts. The fascia lata grafts were obtained via an incision in the middle of the thigh and averaged 14 cm in length and 2.5 cm in width. Care was taken to repair the fascia defect with interrupted 0 nylon in a figure-of-eight fashion during closure of the donor site. The sural nerves were harvested via a series of horizontal 2-cm incisions (Fig. 1).

The facial portion of the procedure is begun by identifying the temporalis muscle tendon on the paralyzed side. A horizontal incision approximately 5 cm in length is created in the hair-bearing region of the temple and extended into the upper preauricular region. A small part of the anterior scalp is elevated and reflected, exposing superficial temporal fascia. The dissection is then carried down to the deep temporal fascia which is opened with an inverted T-shaped incision (with a 2-cm horizontal limb and a 3-cm vertical limb), exposing the underlying temporal fat pad. The fat pad is mobilized a short distance providing access to the distal portion of the temporalis muscle as it courses under the zygomatic arch. The tendinous portion of the temporalis muscle is identified and grasped with a Kocher's clamp (Fig. 2). Progressive tension is applied and the clamps are advanced in a stepwise fashion until the tendon just proximal to the coronoid insertion is reached. The jaw is then opened and closed to confirm good excursion of the tendon after which it is sharply incised, releasing it from its mandibular attachment. Note that in cases of incomplete paralysis where there is a functioning frontalis muscle, we dissect the frontal branch of the facial nerve to preserve its function.

Fig. 3 Fascia lata sutured to temporalis muscle

The fascia lata graft is then firmly secured to the freed tendinous portion of the temporalis muscle with at least ten stitches of 2-0 nylon (Ethicon, Johnson&Johnson Family of Companies,Norderstedt, Germany) in two layers (Figs. 3, 4). Through an incision in the nasolabial fold on the paralyzed side, the upper-lip orbicularis oris, the commissure, and the lower-lip orbicularis oris are exposed. A metal spatula with an orifice is then passed under the zygomatic arch, crossing the buccal fat pad and exiting via the nasolabial fold incision. The free edge of the fascia lata graft is sutured to the spatula. Gentle traction is now applied and the spatula is withdrawn, delivering the distal portion of the fascial graft into the nasolabial incision (Fig. 5). The fascia lata graft is now fixed at four key locations with 3-0 nylon (Ethicon, Johnson&Johnson Family of Companies,Norderstedt, Germany). One point of fixation is at the paralyzed commissure, another at the upper lip, and the other two points of fixation are at the lower lip (Fig. 6). Overcorrection is intentionally done to accommodate postoperative fascial stretching.

Attention is now focused on performing the cross-face nerve grafts. A preauricular incision, similar to that used during facial rhytidectomy, is created. The dissection is then carried through the SMAS and parotid fascia, after which a SMAS flap is elevated under loupe magnification. The dissection proceeds 2 cm anterior to the tragus and

Fig. 4 The temporalis muscle tendon is cut and sutured to the fascia graft

Fig. 5 Fascia lata pulled under zygomatic arch and sutured to nasolabial fold

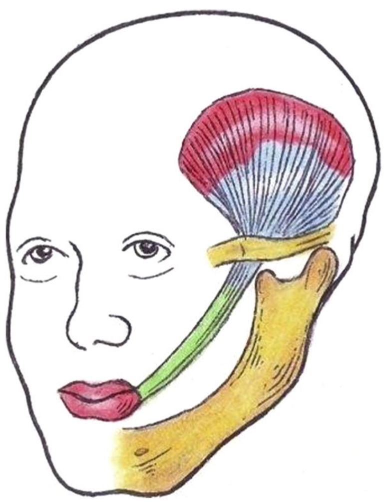

Fig. 6 The fascia lata is attached to the hemiparalyzed lip

Fig. 7 The buccal branch is identified on the paralyzed side

Fig. 8 The buccal branch on the healthy side prior to ETS neurorrhaphy with the sural nerve

within the parotid gland until the buccal branches of the facial nerve are identified bilaterally. Vessel loops are placed around the buccal branches for later neurorrhaphy (Figs. 7, 8). A 1-cm incision is now created in the nasolabial fold on the healthy side. A cylindrical cannula with an attached plastic tube (5-mm diameter) is now passed through the access incisions in stages to create a subcutaneous passage joining the two preauricular surgical sites. The distal end of the sural nerve graft is sutured to the plastic tubing which is slowly retrieved, thus drawing the nerve graft across the face (Fig. 9). At this juncture the microsurgical nerve repair is undertaken with the aid of 3.5× loupe magnification (Fig. 10). Three to four epineural sutures of 8-0 nylon (Ethicon, Johnson&Johnson Family of Companies,Norderstedt, Germany) are utilized to achieve the end-to-side neurorrhaphy. No epineural windows are created in either of the facial nerve branches. A layered closure is performed. A laminar drain is left in the temporal region.

Fig. 9 A sural nerve graft bridges both buccal branches with end-to-side neurorrhaphies

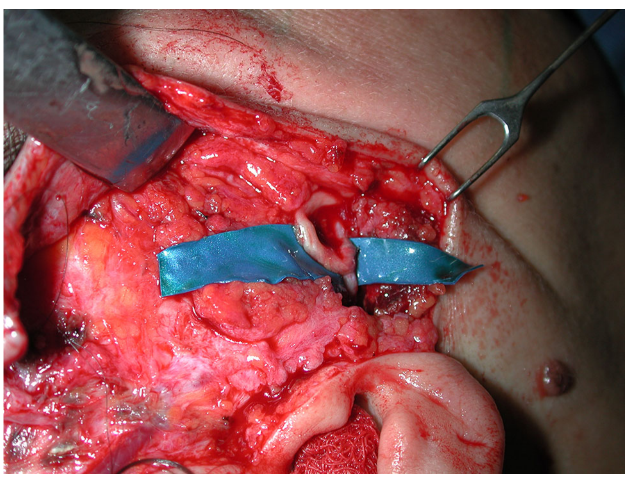

Fig. 10 Nerve graft used for cross-face grafting and ETS neurorrhaphy with buccal branch

The patients were maintained on a soft diet for 3 months and instructed to avoid excessively sweet or sour liquids for 3 weeks to minimize parotid gland stimulation and the potential for fistula formation. The patients are instructed to open the mouth 100 times a day in an effort to prevent formation of tendinous adhesions. Intensive myotherapy is performed on a daily basis in front of a mirror starting 3 months postoperatively and is done for 2 years. The patient is evaluated on a weekly basis by a speech therapist who monitors progress and provides an important source of support and motivation. Excursion of the reanimated hemilip was measured using photographic analysis of images obtained between postoperative month 1 and 84. Patients were photographed in a standard fashion. Frontal views of the face were obtained with the patient's head oriented in the Frankfurt horizontal plain both at rest and during maximum active smiling.

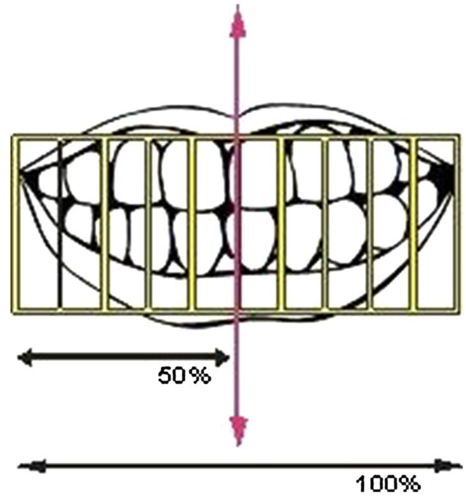

Fig. 11 Schematic representation: feedback to image analysis

Table 1 Percentage of symmetry of a smile before and after surgery, left side, after temporal muscle transposition associated with the cross-face nerve

Patient no.	Affected side	Temporal muscle transposition + cross-face nerve before surgery/ left side (%)	Temporal muscle transposition + cross-face nerve after surgery/left side (%)	Hemilip value (%)
1	R	69	58	50
2	R	59	51	50
3	L	43	49	50
4	R	59	56	50
5	R	53	51	50
6	L	42	40	50
7	R	60	51	50
8	R	68	55	50
9	R	69	58	50
10	L	43	42	50
11	L	22	45	50
12	L	33	45	50
13	R	59	48	50
14	L	29	39	50
15	L	44	45	50
16	L	58	48	50
17	R	55	51	50
18	R	53	49	50
19	R	71	61	50

Table 2 Percentage of symmetry of a smile before and after surgery, right side, after temporal muscle transposition associated with the cross-face nerve

Patient no.	Affected side	Temporal muscle transposition + cross-face nerve before surgery/ right side (%)	Temporal muscle transposition + cross-face nerve after surgery/ right side (%)	Hemilip value (%)
1	R	31	42	50
2	R	41	49	50
3	L	57	51	50
4	R	41	44	50
5	R	47	49	50
6	L	58	60	50
7	R	40	49	50
8	R	32	45	50
9	R	31	42	50
10	L	57	58	50
11	L	78	55	50
12	L	67	55	50
13	R	41	52	50
14	L	71	61	50
15	L	56	55	50
16	L	42	52	50
17	R	45	49	50
18	R	47	51	50
19	R	29	39	50

Length measurements of the paralyzed and unaffected hemilips were obtained using CorelDRAW X3 software (Corel Corp., Ottawa, ON, Canada). In addition, a template was created (Fig. 11) to allow the preoperative and postoperative images to be superimposed for further analysis. The template defined the distance between the right and left commissure as 100 %. A line is then drawn through the central philtrum separating the mouth into a right hemilip (50 %) and left hemilip (50 %). Therefore, values close to 50 % represented minor asymmetries, whereas values significantly less (or more) than 50 % represent major asymmetry.

From the results obtained, representative measures were calculated, including means and standard deviations. The χ^2 test was applied and the 5 % level adopted as significant.

Results

We describe the results of the smile by assessing the left and right hemilips separately so that we could observe the percent change from pre- to postsurgery on the same side. Each hemilip represents 50 % of the mouth, and the closer the results were to 50 %, the more symmetrical the smile.

Table 3 Percentage of difference found between pre and postsurgical smile

Patient no.	Temporal muscle transposition + cross face nerve	
	Presurgical (%)	Postsurgical (%)
1	38	16
2	18	2
3	14	2
4	18	12
5	6	2
6	16	20
7	20	2
8	36	10
9	38	16
10	14	16
11	56	10
12	34	10
13	18	4
14	42	22
15	12	10
16	16	4
17	10	2
18	6	2
19	42	22

Fig. 12 **a** Preoperative photo. **b** Two years after surgery

In the postoperative period of the left hemilip reanimation group, the values were noted to be worse in two cases (patients no. 6 and no. 10 in Table 1). It was also observed that for the right hemilip group, 17 of 19 patients had values approaching 50 % after surgery, thus suggesting symmetry (Table 2).

The percentage difference between pre- and postoperative smiles is given in Table 3. For orthodromic temporalis muscle flap and cross-face nerve grafts using ETS anastomosis, 89.5 % of patients showed significant improvement in the symmetry of their smile.

Fig. 13 **a** Preoperative photo. **b** Two years after surgery

Two-year postoperative results compared with preoperative photos are shown in Figs. 12a, b and 13a, b and videos 1 and 2.

Discussion

Recent advances in microsurgical technique, training, and instrumentation have led to a significant reduction in free-flap thrombosis rates. Despite this increased reliability, the results of free functional muscle transfer for facial reanimation can be unpredictable. Excess muscle volume can prove unsightly, and muscle excursion at times can be inadequate. In addition, the procedures are lengthy in nature. For example, the free gracilis flap is used by many authors, but there are disadvantages such as long operation times, risk of thrombosis leading to total flap loss, and excessive bulk in the face with a resultant asymmetry and unaesthetic appearance [9]. We use this technique only when the patient does not have a functioning temporal muscle.

Another often-used technique is the masseter nerve transfer with sectioning of the masseter nerve and end-to-end neurorrhaphy to the distal stump of the facial nerve trunk [10]. The problem with this technique is the need to section the facial nerve, which can be performed only after confirmation that there is no spontaneous regeneration. This waiting time will cause atrophy of the facial muscles and can lead to suboptimal results. Electromyography is an important assessment tool and some authors use both denervation time as well as electromyographic studies to guide treatment [10, 11].

Perhaps an advantage of the temporalis transfer over the nerve-to-masseter transfer is the restoration of a greater resting tone and better symmetry at repose. However, when smiling, the distal insertion of the temporalis transfer may not match the contralateral nasolabial fold as well as may be achieved with a nerve-to-masseter transfer to the zygomaticus major because with the latter, the muscle insertion into the fold is preserved. To minimize this discrepancy, the fascia lata graft is fixed at four key locations as described above. Furthermore, the temporalis transfer method without sural nerve grafting provided a smile that was rated as good or excellent in 11 of 14 patients [7]. In our method, the temporalis is detached and patients are trained initially to bite only to visualize a smile using a mirror. Subsequently, some patients are able to smile without biting, possibly as a result of brain plasticity [8].

The “babysitter” procedure is indicated in the cases of cross face to prevent muscular atrophy while axonal regeneration occurs [12]. It also requires sectioning of the facial nerve trunk or an important branch, and can be used only when there is no chance of spontaneous regeneration.

The temporalis muscle turn down, as advocated by Gillies (antidromic), can also produce an unsatisfactory result from both a functional and an aesthetic standpoint [13]. The technique utilizes only the central segment of the temporalis and does not take full advantage of the entire muscle contractile force. In addition, it is possible to denervate the central third of the muscle during elevation and some mechanical advantage may be lost when draping the muscle over the zygomatic arch. The fullness produced by turning the muscle over the zygoma in conjunction with the concave temporal defect limits this technique from an aesthetic standpoint.

The orthodromic temporalis muscle flap avoids these drawbacks and seems to be functionally better than the antidromic flap. From an aesthetic point of view, the result is also better as the orthodromic technique does not alter the contour of the temporal fossa or create a protuberance at the zygomatic arch. The tendon is passed through the buccal fat pad, which facilitates good tendinous excursion.

The technique introduced by Labbe and Huault [14] of advancing the temporalis muscle and inserting it more anteriorly in our opinion gives similar results to ours but with a longer surgical time.

Although this article has focused on the combined approach alone, we have performed these approaches separately and we feel that the combined approach provides symmetry and spontaneity to the reanimated smile. In addition to augmenting neural input to facial muscles, we hypothesize that the sural nerve graft develops collateral axonal sprouting and directly neurotizes the temporalis muscle.

Another potential advantage is that the cross-face nerve graft with end-to-side neurorrhaphy does not injure the facial nerve and, therefore, can be utilized in relatively early cases of facial paralysis where some additional spontaneous nerve regeneration may occur. A further benefit is the relatively short duration of the procedure. Utilizing a two-team approach, surgery can be completed in 2–4 h.

Several techniques have been developed to measure mouth movement in facial paralysis; however, many of the methods are complex, expensive, and may not yield superior information to more simple measures. Many measuring techniques fail to address the concept of symmetry, which is of paramount importance. The House–Brackmann scale is one of the oldest and most utilized methods of describing facial weakness. It provides some quantification about facial symmetry but lacks emphasis on this important surgical end point. Methods using computerized analysis of movies are able to get all the patient angles, but they are time consuming and expensive. For this reason we are evaluating surgical outcomes by assessing symmetry by measuring the percent length of the hemilip. In our opinion, achieving symmetry is the most important surgical goal. Strong cheek motion and powerful lip excursion are of little value if they yield significant smile asymmetry.

We have chosen to measure the hemilips photographically because it is simple, inexpensive, accurate, reproducible and capable of being used in cases that have been operated on previously. It is important to emphasize that although these values are subjective, they depend on voluntary emotional actions of patients, and they also rely on their cooperation and collaboration. These obstacles, however, are present in any method used for this purpose. The photographic data are also supported by preoperative and postoperative video analysis which demonstrated significant improvements in symmetry by the high patient satisfaction rate.

Conclusion

The combination of two surgical methods, orthodromic temporalis muscle flap and cross-face nerve graft (buccal–buccal with end-to-side neurorrhaphy), is simple, allows predictable results in most cases, has no risk of thrombosis, and is easily reproducible. The results were adequate in almost 90 % of cases and produced a natural and synchronized smile.

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Conflict of interest The authors have no conflicts of interest to disclose.

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