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ORIGINAL ARTICLE

M-Mode Echomyography of Facial Muscle Function Following Facial Reanimation with Temporalis Muscle Galea Pedicled Flap: Analysis of Ten Cases with Review of Literature

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Abstract
Introduction Facial palsy is a condition where the patients lack voluntary movement on the affected side of the face and are not able to convey their emotions. Besides that, they also succumb themselves to social isolation. Various techniques have been devised to overcome this devastating problem. The aim of this article is to evaluate and compare facial muscle function before and after facial reanimation with temporalis muscle galea pedicled flap by motion mode echomyography in patients with long-standing facial paralysis.
Patients and Methods Ten patients with long-standing facial paralysis were included in the study (six patients with LMN palsy and four patients with facial weakness involving specific peripheral branches), and they subsequently underwent facial reanimation surgery with temporalis galea pedicled flap. These patients were followed postoperatively for a period of 1–2 years and were subjectively graded as excellent, good, fair and poor and objectively evaluated by M-mode echomyography, and the results were evaluated and statistically analyzed.
Results Subjectively, out of 6 patients with LMN palsy, results were graded as excellent in 2 cases, good in 3 cases, fair in 1 case, and out of 4 patients with weakness in specific facial nerve branches, the subjective results were excellent in 2 cases, good in 1 case and fair in 1 case. Objectively, the effect of transposed temporalis galea on orbicularis occuli, levator labii superioris and orbicularis oris was found to be statistically significant in patients with LMN palsy.
Conclusion Our study proves the versatility of temporalis muscle galea pedicled flap in cases of long-standing facial paralysis by motion mode echomyography.

Keywords Facial paralysis · Reanimation · Temporalis galea

Introduction

Human face comprises of one of the most complex musculoskeletal units which gives rise to myriad of facial expressions that can reflect every possible emotion that the human mind can conjure. Patients with long-standing facial paralysis lack facial expressions, and they exhibit lower eyelid ectropion and buccinator dysfunction on the affected side of the face [1].

Reanimation of facial paralysis becomes a difficult clinical problem particularly in long-standing cases. Various surgeons have propagated numerous techniques from the beginning of this nineteenth century for instilling life into the paralyzed face [2]. Pedicled muscle flap transfer, a dynamic method of reanimation, is preferred in cases where microvascular anastamosis cannot be done [3, 4].

Transfer of dynamic muscular sling requires meticulous planning, selection of the donor muscle site, determining

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the size, shape, contractile properties and knowledge about neural connections of the muscle belly [5, 6]. Of the various dynamic techniques that have been advocated for the reanimation of long-standing facial paralysis, masseter and temporalis muscle were commonly used for transposition [7–12].

Inadequate flap length remains the main problem with this temporalis transposition in the past. To counteract this problem, many modified methods such as removing the middle portion of the zygomatic arch have been proposed. The combined application of a temporalis muscle transfer to the upper face and masseter muscle transfer to the lower face and using fascia lata to connect the extremities of the flap have also been reported in the literature [13–15].

But these procedures cause additional morbidity to the patient such as removal of bone from the zygomatic arch, involvement of secondary surgical site and involvement of more than one muscle. Moreover, the results tend to be unsatisfactory.

The use of a new flap consisting of the pedicled temporalis muscle, temporal fascia and galea together, described initially by Mathog et al. and Hu et al. [1, 15], helps to counteract all the above-said difficulties and covers large areas of the face and reanimate eye, nose and mouth deformities. It therefore serves as an effective way of dealing cases of long-standing facial paralysis.

Therefore, the aim of this study is to evaluate the versatility of temporalis muscle galea pedicled flap and to compare pre- and postoperative facial muscle function following facial reanimation by M-mode echomyography in treatment of long-standing facial nerve paralysis.

Patients and Methods

Ten patients (7 females and 3 males) with long-standing facial paralysis underwent facial reanimation with temporalis muscle galea pedicled flap after getting prior consent. This included 6 patients with LMN palsy and 4 patients with facial weakness involving specific peripheral branches. All patients in our study had facial paralysis for more than 2 years with a range of 2–29 years.

Out of six patients (5 females and 1 male) with lower motor neuron (LMN) facial palsy, one half had a history of exposure to cold, two patients had congenital history, and one patient had a history of viral fever in childhood (Table 1). Out of 4 patients (2 males and 2 females) with facial weakness involving specific peripheral branches in the right side of face, 3 patients had weakness along the distribution of marginal mandibular nerve and one patient had weakness along distribution of zygomatic branch of facial nerve. One half of this group had congenital history, and another half had history of trauma (Table 1).

Surgical Technique

The operative procedure was done as described by Hu et al. [1] with a minor modification. Rhytidectomy incision from the anterior tragus through temple region was made to reach the occipital rear. Another frontward slanting incision was made in the scalp in the shape of "Y" approximately for about 8 cm. Layered dissection was done. On the surface of SMAS, the superficial temporal fascia and galea were separated (Fig. 1). Incisions were made on the galea, temporal fascia and temporalis muscle to form a rectangular pedicled flap, and these layers were sutured to form a single flap that goes down 2 cm superior to zygomatic arch. The temporalis muscle and galea were sutured as a minor modification to the original procedure as it provided additional strength and prevents shearing of galeal flap from temporalis muscle.

The distal end of the flap was then split lengthways into four compartments, and the split flaps were inserted through subcutaneous tunnels made to the mouth, nasal ala and lower eyelid (Fig. 1) Several 0.5-cm-long incisions were made at the oral commissure, nasal ala and medial canthus on the affected side as well as in the upper and lower lips on the normal side (Fig. 1).

The fascia strips were sutured with the ipsilateral orbicularis muscle of the oral commissure, nasal ala, medial canthal ligament and the contralateral orbicularis muscle of the upper and lower lips. Suspending force was applied to keep the oral commissure, nasal ala and lower eyelid of the palsy side in an overcorrected position in relation to the normal side. Suturing was done in layers. Drains were inserted, and dressing was done.

All our patients underwent postoperative physiotherapy exercises for training in mastication and facial expression after 3 weeks [1]. The facial muscles were also electrically stimulated by transcutaneous electric nerve stimulation (TENS). The intensity of stimulation was adjusted to mimic the natural action of the facial muscles. Muscles were stimulated to achieve eye closure and oral control and to maintain symmetry during smile. Follow-up was done for a period of 1–2 years, and the effect of transposed temporalis galea on facial muscles was evaluated subjectively and objectively as below.

Postoperative Functional Assessment

Subjective Analysis

The subjective results were graded as excellent, good, fair and poor as suggested by May and Druker [7].

Table 1 Preoperative evaluation of facial muscle function

	Patient	Age/sex	Type of facial palsy and deformity	Etiology	Duration of palsy (years)	Closure of eye	Symmetry of lips	Difficulty in eating	Difficulty in speaking	Drooling of saliva
Patients with LMN facial palsy	1	29/M	LMN Rt s ide	Congenital	29	−	−	+	+	+
	2	21/F	LMN Lt s ide	Exposure to Cold	3	+	−	+	+	+
	3	20/F	LMN Lt s ide	Congenital	20	−	−	+	+	+
	4	32/F	LMN Lt s ide	Exposure to Cold	2	−	−	+	+	+
	5	25/F	LMN Rt s ide	Exposure to Cold	2	−	−	+	+	+
	6	23/F	LMN Rt s ide	Viral fever	23	−	−	+	+	+
Patients with facial weakness involving specific peripheral branches	7	30/F	Facial weakness involving marginal mandibular branch Rt side	Trauma	2	+	−	+	+	+
	8	28/F	Hemifacial microsomia with marginal mandibular nerve weakness Rt side + facial asymmetry with occlusalcant	Congenital	28	+	−	+	+	+
	9	23/M	Hemifacial microsomia with marginal mandibular nerve weakness Rt side + facial asymmetry with occlusalcant	Congenital	23	+	−	+	+	+
	10	25/M	Facial weakness involving temporal and zygomatic branch Rt side	Trauma	2	−	+	−	−	−

LMN lower motor neuron, *Rt* right side, *Lt* left side

+ denotes presence, − denotes absence

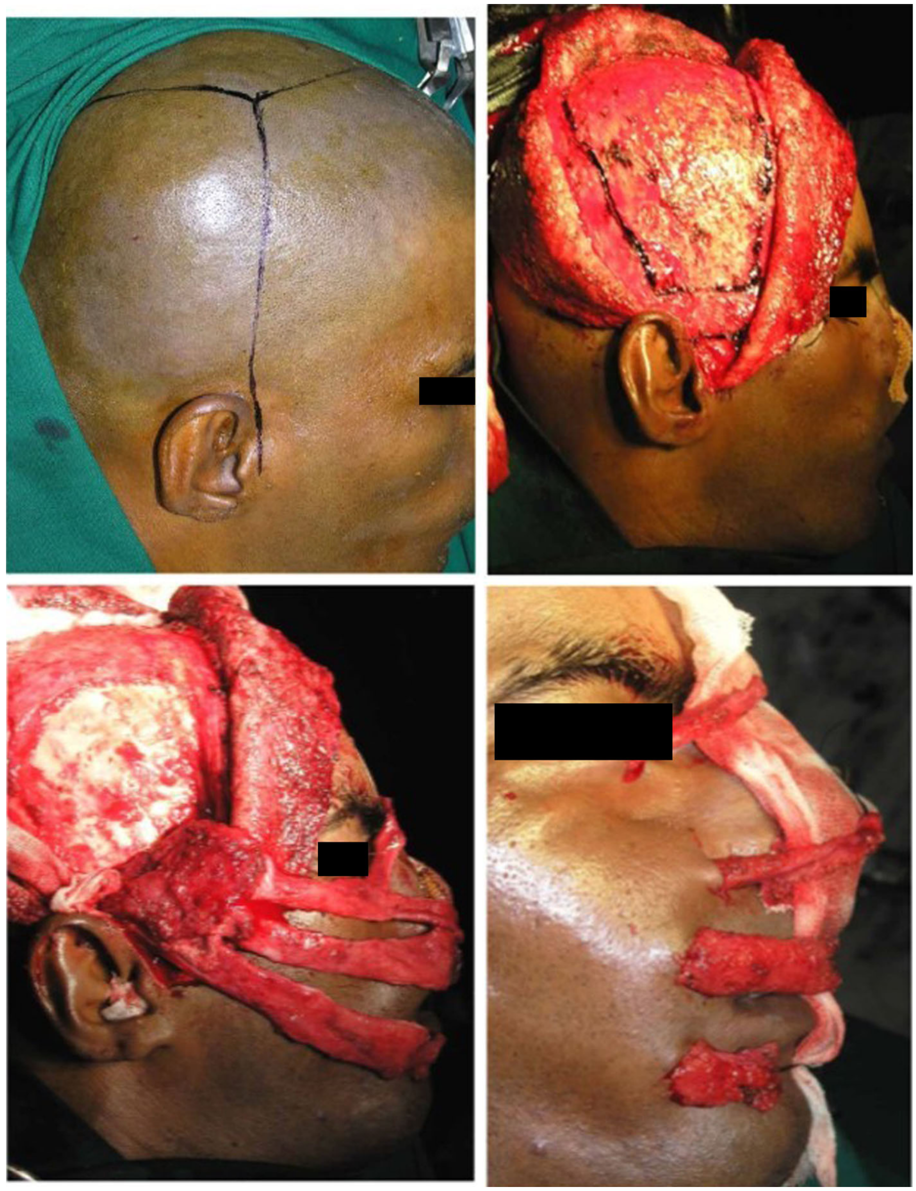
1. Excellent—complete closure of paralyzed eyelids, facial symmetry at rest and during smile and restoration of functions like pursing of lips.
2. Good—complete closure of paralyzed eyelids and facial symmetry at rest and during smile, but slight weakness during pursing of lips.
3. Fair—incomplete closure of paralyzed eyelids, facial asymmetry at rest and during smile, and complete weakness during pursing of lips.
4. Poor—no change.

Objective Analysis

Objective analysis was done through M-mode (MOTION MODE) echomyography to determine the functional efficiency of facial muscles and effect of transposed temporalis galea on facial muscles [16]. The contractions and relaxations of orbicularis oculi, levator labii superioris, levator anguli oris, depressor labii inferioris, orbicularis oris and temporalis were evaluated pre- and postoperatively.

In patients with LMN type of palsy, no muscle contraction was observed preoperatively. In patients with facial weakness involving only specific peripheral

Fig. 1 Surgical technique depicting transfer of temporalis galea pedicled flap to facial muscles of affected side



branches, evaluation was done only on specific muscles according to nerve paralyzed. Postoperatively, the effect of transposed temporalis galea on these facial muscles was evaluated in all the patients.

Mean amplitude and fractional shortening values were obtained in all patients, and the results were statistically analyzed using Wilcoxon matched pairs signed rank test. P value less than 0.05 was considered significant.

Results

Out of 6 patients with LMN palsy, the subjective results were graded as excellent in 2 cases (33%), good in 3 cases (50%) and fair in 1 case (17%) (Fig. 2 shows preoperative and postoperative eye closure, and Fig. 3 shows pre- and post-op smile of a patient with LMN facial palsy on the right side). Out of 4 patients with specific facial weakness, the subjective results were excellent in 2 cases (50%), good in 1 case (25%) and fair in 1 case (25%).

Objectively, the effect of transposed temporalis galea on orbicularis occuli, levator labii superioris, orbicularis oris muscles was found to be statistically significant in patients with LMN palsy (Table 2) and only clinically significant in patients with specific facial muscle weakness (Table 3).

It was also noted that the results of muscle transposition have been enhanced in patients who underwent active physiotherapy regularly. It was also observed that unless the patient is consciously contracting the transposed

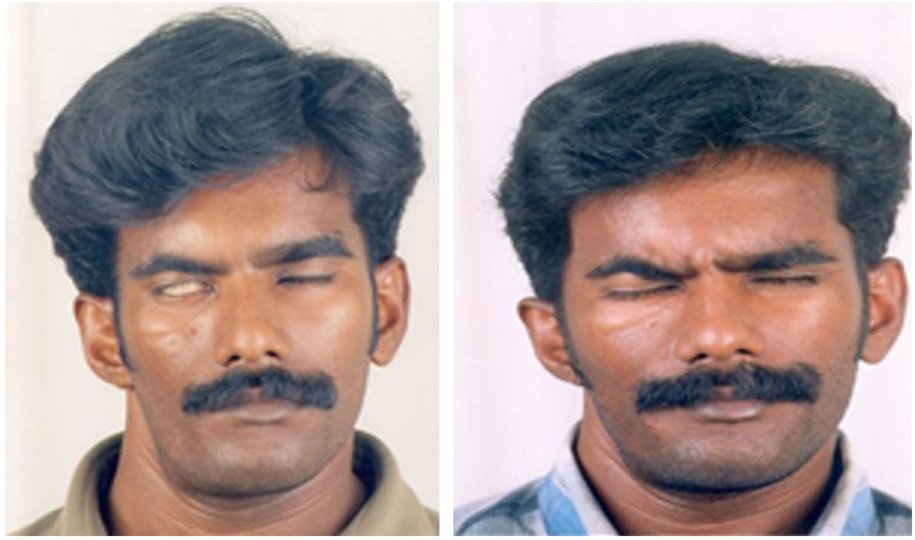


Fig. 2 Preoperative and postoperative eye closure

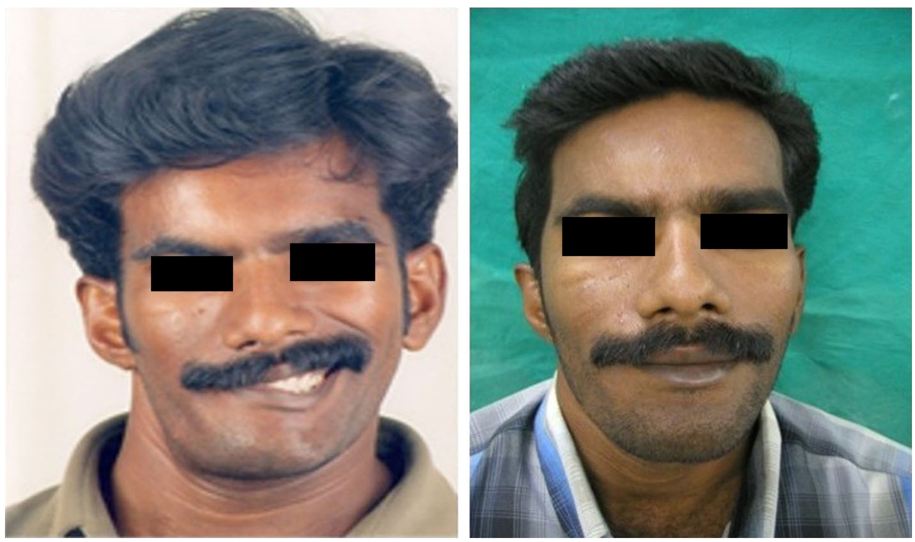


Fig. 3 Preoperative and postoperative smile

muscle in conjunction with smiling to the proper degree on the non-paralyzed side, symmetry is unlikely.

Discussion

Facial expression is an integral component of human expression and communication. The salubrious nature of patients affected with facial paralysis not only restricts them with functional and cosmetic deformity but also creates a psychological depression in them.

In order to overcome this problem, various techniques have been tried for rehabilitation of paralyzed face [7, 17]. In long-standing facial paralysis, severe neurofibrosis and myofibrosis take place which make reinnervation impossible. Patients with congenital or developmental facial paralysis also cannot be reinnervated due to lack of development of neuromuscular units of face. In such cases, muscle transfers are attempted [18].

The results obtained through static support were not satisfying due to lack of blood supply, infection, fibrosis and necrosis. In such situations, regional muscle transfer, suggested by Baker and Conley [17], remains an excellent option for reanimation of long-standing facial paralysis.

Among regional muscle transfer, transposition of temporalis and masseter are popular and most accepted [17]. Labbe et al. found that masseter myoplasty has the disadvantage of providing a horizontal action on the lip commissure which is not physiologic [12, 19]. On the contrary, temporalis transfer allows physiologic 45° traction to the occlusal plane and its success in facial reanimation has been already reported by various authors [17, 20–25].

But the major disadvantage of all these above-mentioned methods was limitation of motion caused by failure

Table 2 Comparison of mean values of temporalis and other muscles postoperatively in patients with LMN palsy

Variable	Mean ± S. D	Difference Mean ± S. D	*P* value*
'A' only			
M1	3.46 ± 0.38		
M2	3.38 ± 0.28	0.08 ± 0.44	0.03 (Sig)
M1	3.63 ± 0.54		
M3	3.67 ± 0.49	0.03 ± 0.48	0.69 (Ns)
M1	3.63 ± 0.54		
M4	3.47 ± 0.33	0.17 ± 0.46	0.039 (Sig)
M1	3.63 ± 0.54		
M5	3.43 ± 0.29	0.20 ± 0.51	0.53 (Ns)
M1	3.63 ± 0.54		
M6	3.70 ± 0.52	0.07 ± 0.51	0.043 (Sig)
'FS' only			
M1	19.33 ± 2.58		
M2	22.62 ± 1.53	3.29 ± 2.00	0.04 (Sig)
M1	19.39 ± 2.32		
M3	22.31 ± 1.09	3.97 ± 3.13	0.03 (Sig)
M1	19.39 ± 2.32		
M4	22.31 ± 1.09	2.91 ± 2.53	0.07 (Ns)
M1	19.39 ± 2.32		
M5	21.66 ± 2.40	2.27 ± 3.13	0.12 (Ns)
M1	19.39 ± 2.32		
M6	24.69 ± 2.36	5.29 ± 3.76	0.046 (Sig)

M1—temporalis, M2—orbicularis occuli, M3—levator labii superioris, M4—levator anguli oris, M5—depressor labii inferioris, M6—orbicularis oris

A amplitude of contraction, *FS* fractional Shortening

**P* value < 0.05 is considered significant

of muscle to reach large areas of face [15]. To cover large areas of face and to reanimate eye, nose and mouth deformities with one flap, pedicled temporalis muscle, temporal fascia and galea together have been used in paralyzed face and the results are quite promising [1].

While transposing temporalis galeal flap to eyelids, the use of two separate strips of tissue on the lower and upper eyelids is not necessary. Just one strip from the flap transferred to the lower eyelid can close a paralyzed eye completely. To achieve this, it is necessary to suture the extremity of the flap at a high position in the medial canthus ligament.

Suturing the extremity of the flap with the orbicularis oris of the contralateral side through each lip tunnel is extremely important to achieve final dynamic appearance of mouth [20].

This muscle flap procedure used by us has specific advantages. The temporalis muscle can be lengthened in continuity with its natural galeal attachments. Fascial slips are not necessary, and the procedure need not rely on flimsy epicranial extensions. Additional advantages include ease of usage with no loss of significant function. This procedure also eliminates second surgical site and donor site morbidity as in fascia lata.

As with other temporalis transfer techniques, the direction of pull of muscle is useful as it allows physiologic 45° traction to the occlusal plane. The temporalis muscle with galea will pull up and laterally on the mouth to evoke a smile, and across the eyelids to close the palpebral tissue. Theoretically, a patient could learn to operate one muscle area independently of the other. A smile can be obtained with eye closure, and on command, the eyes can be closed without a smile. In all our cases, satisfactory middle and lower facial motion were achieved.

Another advantage of this technique is providing tissue bulk to the cheek in patients with atrophied facial muscles due to long-standing facial paralysis. The main disadvantage of temporalis muscle galea flap transfer is that motion must be triggered by a muscle of mastication rather than by one of facial expressions. The movements must be learned, and much time must be spent in education to achieve effective mobility. Emotion and feeling must be recognized by the patient and then voluntarily transferred to a facial expression.

Hair loss is a possibility when its follicle is burnt while using cautery. Though hair loss was initially seen in our patients, they did return within 3 months postoperatively. This technique creates a bulge caused by the folding part of the temporalis muscle at the superior border of the zygomatic arch on the paralyzed side. But this can be partly hidden by hair, especially in female patients. Besides that, this procedure does not take the advantage of myoneurotization. Postoperatively pain and discomfort occurred initially for few days in all our patients which were managed with routine antibiotics and analgesics.

Though our technique involved extensive incision that courses from the anterior tragus to the temple to reach the occipital rear and a frontward slanting incision similar to letter "Y," due to meticulous dissection and hemostasis, the blood loss was less than 400 ml. None of our patient required blood transfusion in our series.

Regular training in mastication and facial expression with physiotherapy exercises and TENS therapy began in all our patients after 3 weeks of operation. We observed that during initial training, patients need to put great effort to obtain voluntary control of selected facial regions. Each movement has to be constantly thought about and felt, and only after 3–4 months of practice, that patients acquire acceptable, new and automatic patterns of facial movement. Appropriate facial movements have to be practiced selectively in front of a mirror.

Table 3 Comparison of mean values between pre-op and post-op in patients with specific facial weakness

Variable	Pre-op Mean ± S. D	Post-op Mean ± S. D	Change Mean ± S. D	P value*
'A' only				
M1	3.65 ± 0.40	3.15 ± 0.24	0.50 ± 0.18	0.07 (Ns)
M2	2.20 ± 0.0	3.70 ± 0.0	–	–
M3	2.33 ± 0.80	3.50 ± 0.50	1.17 ± 0.31	0.11 (Ns)
M4	2.73 ± 0.59	3.23 ± 0.65	0.50 ± 0.20	0.11 (Ns)
M5	2.37 ± 0.71	2.97 ± 0.95	0.60 ± 0.27	0.11 (Ns)
M6	1.90 ± 0.20	3.60 ± 0.56	1.70 ± 0.70	0.11 (Ns)
'FS' only				
M1	21.43 ± 2.51	18.38 ± 1.53	3.05 ± 2.48	0.14 (Ns)
M2	17.05 ± 0.0	24.3 ± 0.0	–	–
M3	16.49 ± 5.68	21.60 ± 5.51	5.11 ± 0.18	0.11 (Ns)
M4	19.45 ± 6.02	21.37 ± 3.43	1.93 ± 2.59	0.29 (Ns)
M5	20.16 ± 3.61	20.27 ± 4.63	0.11 ± 2.60	1.00 (Ns)
M6	15.42 ± 2.74	21.80 ± 1.76	6.38 ± 4.14	0.11 (Ns)

M1—temporalis, M2—orbicularis occuli, M3—levator labii superioris, M4—levator anguli oris, M5—depressor labii inferioris, M6—orbicularis oris

A amplitude of contraction, *FS* fractional shortening

*P value < 0.05 is considered significant

It has been stated in studies that greatest improvement occurs within 6 months of rehabilitation therapy and may last for 12 months and beyond depending on patient progress postoperatively [23].

Our follow-up has shown that this training leads to good movement on affected side and that facial expressions become more and more symmetrical.

Conclusion

The application of temporalis muscle galea pedicled flap is one-stage reanimation procedure with proven success and is a dynamic method of reanimation for patients affected by long-standing facial paralysis. It is possible to reanimate larger areas of face with a single flap compared to other flaps, thereby proving the versatility of this technique.

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Compliance with Ethical Standards

Conflict of interest None.

Informed Consent Informed consent and permission to use patient's photographs have been obtained.

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