

A Simple Method for Reconstruction of the Temporalis Muscle Using Contourable Strut Plate after Pterional Craniotomy: Introduction of the Surgical Techniques and Analysis of Its Efficacy

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Objective : Pterional craniotomy (PC) using myocutaneous (MC) flap is a simple and efficient technique; however, due to subsequent inferior displacement (ID) of the temporalis muscle, it can cause postoperative deformities of the muscle such as depression along the inferior margin of the temporal line of the frontal bone (DTL) and muscular protrusion at the inferior portion of the temporal fossa (PITF). Herein, we introduce a simple method for reconstruction of the temporalis muscle using a contourable strut plate (CSP) and evaluate its efficacy.

Materials and Methods : Patients at follow-ups between January 2014 and October 2014 after PCs were enrolled in this study. Their postoperative deformities of the temporalis muscle including ID, DTL, and PITF were evaluated. These PC cases using MC flap were classified according to two groups; one with conventional technique without CSP (MC Only) and another with reconstruction of the temporalis muscle using CSP (MC + CSP). Statistical analyses were performed for comparison between the two groups.

Results : Lower incidences of ID of the muscle ($p < 0.001$), DTL ($p < 0.001$), and PITF ($p = 0.001$) were observed in the MC + CSP than in the MC Only group. The incidence of acceptable outcome was markedly higher in the MC + CSP group ($p < 0.001$). ID was regarded as a causative factor for DTL and PITF ($p < 0.001$ in both).

Conclusion : Reconstruction of the temporalis muscle using CSP after MC flap is a simple and efficient technique, which provides an outstanding outcome in terms of anatomical restoration of the temporalis muscle.

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INTRODUCTION

Frontotemporal craniotomy, also known as "pterional craniotomy" (PC), provides an optimal microscopic exposure and a wide open working space for manipulation of intracranial structures, and it has been wide-

ly used in the field of neurosurgery for treatment of lesions in the anterior and posterior circulations.⁹⁾ When Yasargil¹⁷⁾ first described standard techniques and procedures for PC in his publication in 1984, subgaleal dissection was used for separation and mobilization of the temporalis muscle. Because subgaleal

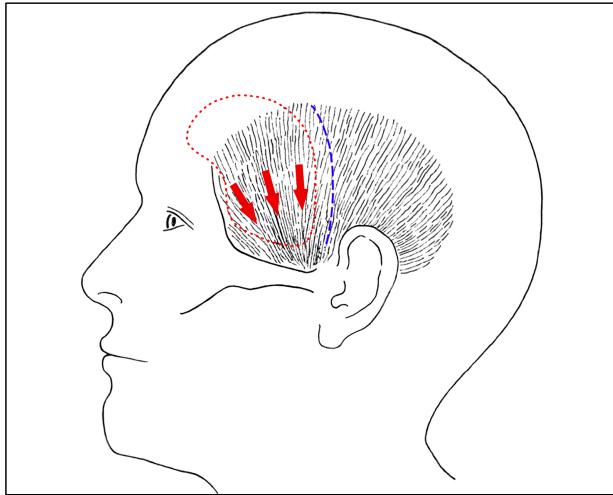


Fig. 1. The illustration depicts the course of fibers of the temporalis muscle and the direction of displacement, or sliding, (red arrows) of unattached temporalis muscle after pterional craniotomy (PC). The size and shape of PC (red dotted line) and the incision line on the temporalis muscle (blue dotted line) are also shown.

dissection of the temporalis muscle bears significant risk of injury to the frontal branches of the facial nerve, various surgical techniques have been adopted such as interfascial and subfascial dissection. However, interfascial dissection is somewhat complex and time-consuming, and, because the facial nerve sometimes courses into the interfascial space, it still cannot eliminate the risk of facial nerve injury. Subfascial dissection is also time-consuming, and may result in injury to muscle fibers and intramuscular bleeding. These two techniques require transection of the temporalis muscle to leave a cuff for closure, which causes functional and cosmetic problems by muscle fibrosis and atrophy.¹⁾⁵⁾⁶⁾¹¹⁾¹⁵⁾¹⁸⁾ To minimize the risk of facial nerve injury and temporalis muscle atrophy, another technique of dissecting the temporalis muscle and skin as one flap, known as myocutaneous (MC) flap, was introduced, and this technique is now commonly used.⁶⁾ Although it is a simple and quick method, inadequate anatomical restoration of the temporalis muscle can cause cosmetic problems such as depression along the inferior margin of the temporal line of the frontal bone and muscular protrusion at the inferior portion of the temporal fossa due to sub-

sequent inferior displacement, or sliding, of the temporalis muscle, and is eventually exacerbated by unexpected atrophy and fibrosis (Fig. 1, 2).

According to previous reports, the majority of patients with even minor postoperative deformities experience cosmetic complexes and functional handicaps. Therefore, neurosurgeons should be aware of not only the clinical outcomes but also the cosmetic and functional outcomes after intracranial procedures.⁷⁾

This study was conducted in order to introduce a simple and quick surgical method for reconstruction of the temporalis muscle using a contourable strut plate (CSP) and to evaluate the efficacy of this technique by analyzing the clinical results in patients who underwent PC using MC flap in comparison with those treated with previous techniques without CSP.

MATERIALS AND METHODS

Data collection and patient enrollment

Patients who visited the outpatient department (OPD) at our institute between January 2014 and October 2014 for follow-ups after PCs were candidates for this study. All of them underwent PCs performed by a single neurosurgeon using MC flap with or without CSP for treatment of cerebral aneurysms. Patients who underwent additional cosmetic procedures such as injections or fat grafts were excluded. Outcomes after reconstruction of the temporalis muscle were evaluated at OPD by gross inspection and also on the axial images of three-dimensional computed tomography (CT) scan at least more than three months after surgery, and the results were assigned to one or more of the following categories: (1) inferior displacement (ID), or sliding, of the temporalis muscle, (2) depression along the inferior margin of the temporal line of the frontal bone (DTL), (3) muscular protrusion at the inferior portion of the temporal fossa (PITF), or (4) none. The patient's profiles, sides of lesions, diagnoses, presence of deformities after reconstruction of the temporalis muscle, and complications such as instrument failures or postoperative in-

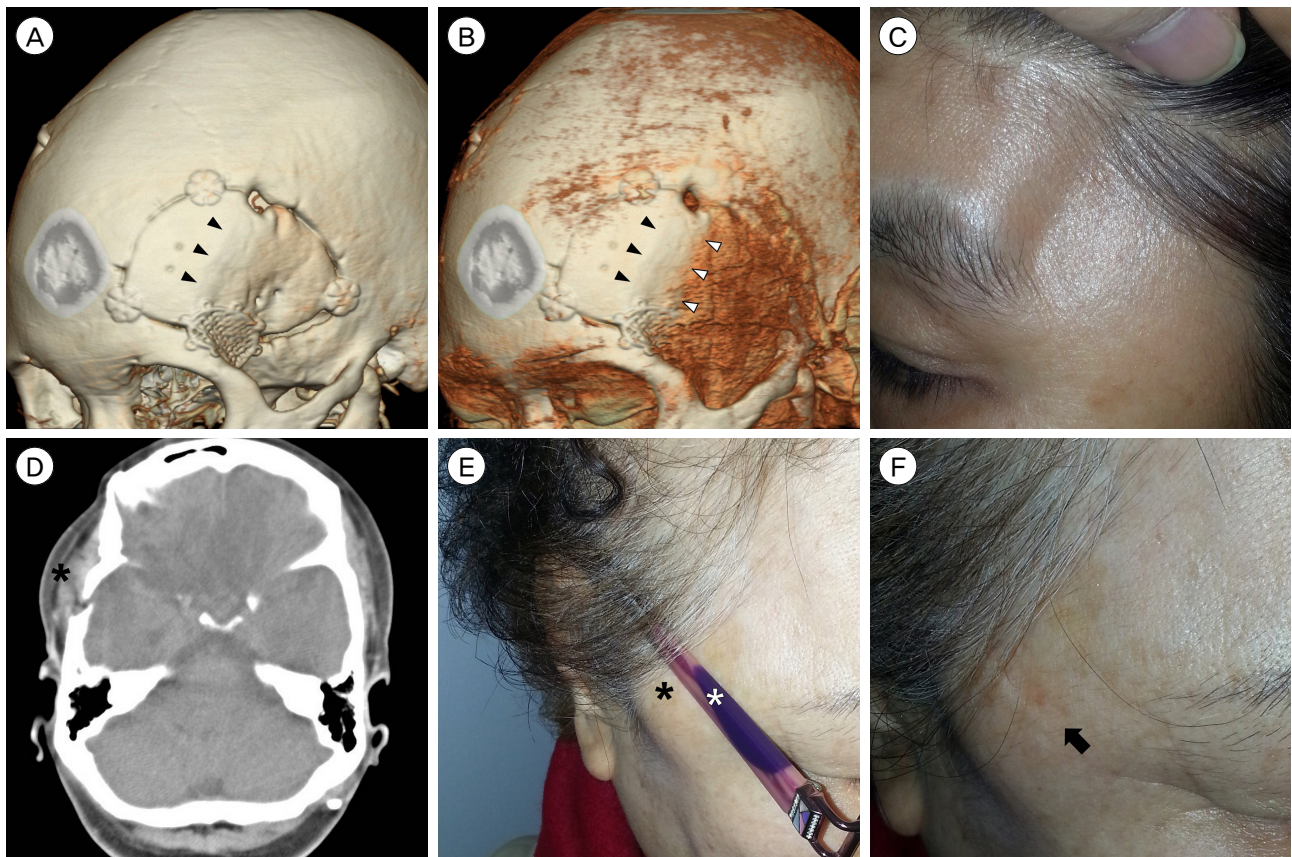


Fig. 2. Three-dimensional computed tomography (CT) scans (A, B) of a patient demonstrate the temporal line of the frontal bone (black arrowheads) and the displaced attachment site of the temporalis muscle (white arrowheads). A photograph (C) of the same patient shows a marked depression along the inferior margin of the temporal line of the frontal bone. The axial CT image (D) of a patient demonstrates a muscular protrusion at the inferior portion of the temporal fossa (black asterisk). Photographs (E, F) of the same patient show that this temporal protrusion (black asterisk) may cause discomfort when wearing glasses (white asterisk). Note the imprint on the skin (black arrow) after taking the glasses off.

fections were recorded in detail. These prospectively maintained databases including medical records and radiological images were reviewed retrospectively.

These PC cases using MC flap were classified according to two groups; one with conventional technique without CSP (MC Only) and another with reconstruction of the temporalis muscle using CSP (MC + CSP). In both groups, keyhole site defect was reconstructed using "temporal mesh floating techniques" as described by Lee et al.¹⁰ For the MC + CSP group, one titanium CSP (Synthes GmbH, Oberdorf, Switzerland) of 35 × 12.5 mm in size and 0.4 mm in thickness with eight screw holes was used. It is malleable and easily bent into various shapes which fit on the underlying bony contour (Fig. 3).

Technique for reconstruction of the temporalis muscle using CSP

After fixation of the craniotomy bone using instruments such as mini-plates, titanium clamps, or burr

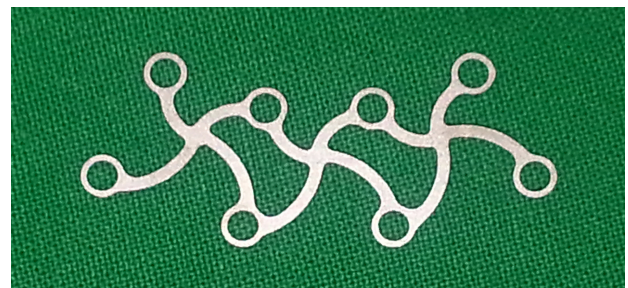


Fig. 3. The photograph shows the structure of a contoured strut plate (Synthes GmbH, Oberdorf, Switzerland). It is malleable and easily bent into various shapes which fit on the underlying bony contour.

hole covers, keyhole defect was repaired by temporal mesh floating technique.¹⁰ CSP was slightly bent into the contour of the temporal line of the frontal bone, and fixed to the temporal line using two low profile self-tapping screws. The antero-inferior portion of the temporalis muscle was sutured over the temporal mesh. The edge of the temporalis fascia and muscle was sutured again and fixed to the CSP, which is the site of original attachment (Fig. 4).

Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, IL, USA). For comparison of MC Only and MC + CSP groups, Pearson's *chi-square* test and Fisher's exact test were performed for the catego-

rical variables, and Student's *t*-test for the continuous variables. Simple regression analyses were performed to determine the cause-and-effect relationships between the variables. The results were considered significant for probability value (*p* value) less than 0.05.

RESULTS

Overall 106 PC cases in 95 patients with 134 aneurysms were finally enrolled in this study. Eleven patients underwent PCs on both sides in the different sessions for treatment of multiple bilateral aneurysms, and each side was separately evaluated. Eighty cases (18 males and 62 females, mean age of 55.0 ± 9.2 years) were enrolled in the MC Only group, and 26 (10 males and 16 females, mean age of 57.7 ± 9.6

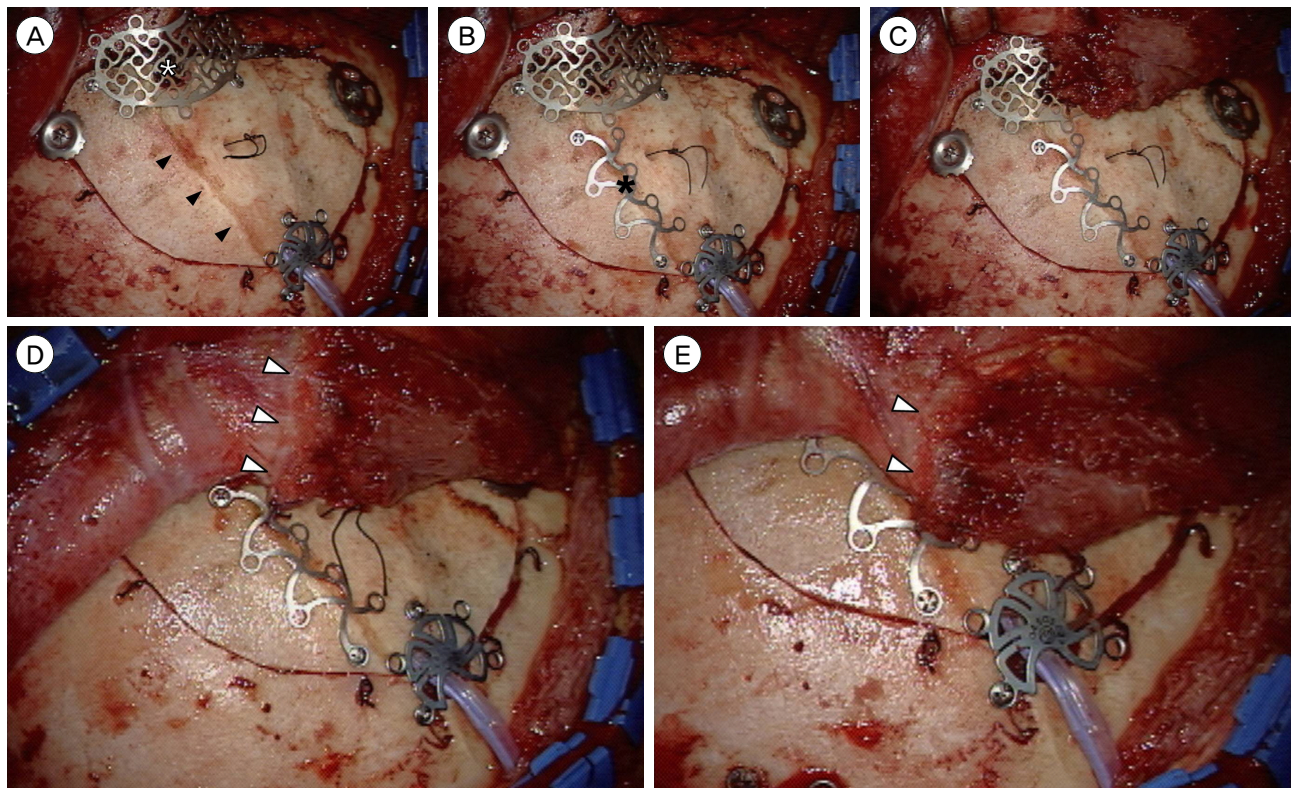


Fig. 4. Intraoperative photographs demonstrate the technique for reconstruction of the temporalis muscle using a contourable strut plate (CSP). (A) After fixation of the craniotomy bone using instruments such as mini-plates, titanium clamps, or burr hole covers, keyhole defect is repaired by temporal mesh floating technique (white asterisk). The temporal line of the frontal bone is indicated by black arrowheads. (B) A CSP (black asterisk) is slightly bent into the contour of the temporal line of the frontal bone and fixed to the temporal line using two low profile self-tapping screws. (C) The antero-inferior portion of the temporalis muscle is sutured over the temporal mesh. (D, E) The edge of the temporalis fascia and muscle (white arrowheads) is sutured and fixed to the CSP, which is the site of original attachment.

years) in the MC + CSP group. There were no statistical differences in sex and age between the two groups ($p = 0.109$ by *chi-square* test and $p = 0.357$ by *t*-test respectively). However, there was statistical difference in the side of craniotomy ($p = 0.032$ by *chi-square* test), left dominant in the MC Only group and right dominant in the MC + CSP group, although this difference would not have actually affected the surgical outcomes (Table 1).

ID of the temporalis muscle was detected on the three-dimensional CT scans in 40 cases (37.7%); 40 (50%) in the MC Only group and none (0%) in the MC + CSP group, and the incidences were statistically different between the two groups ($p < 0.001$ by Fisher's exact test) (Fig. 2A, B). DTL was observed in 27 cases (25.5%); 27 (33.8%) in the MC Only group and none (0%) in the MC + CSP group, and the incidences were statistically different between the two groups ($p < 0.001$ by Fisher's exact test) (Fig. 2C).

PITF was observed in 20 cases (18.9%); 20 (25%) in the MC Only group and none (0%) in the MC + CSP group, and the incidences were also statistically different ($p = 0.001$ by Fisher's exact test) (Fig. 2D-F). Fifty-one cases (63.8%) in the MC Only group and all 26 cases (100%) in the MC + CSP group did not have DTL and PITF regardless of presence of ID of the temporalis muscle on the CT scans, indicating absence of definite cosmetic deformities of the temporalis muscle (Fig. 5). The incidences of absence of the deformities were also statistically different ($p < 0.001$ by *chi-square* test) (Table 1).

Of 40 cases with ID of the temporalis muscle, 27 cases (67.5%) had DTL, 19 (47.5%) had PITF, 18 (45%) had both DTL and PITF, and 12 (30%) had neither DTL nor PITF. Only in one case, PITF was observed even without definite ID of the temporalis muscle. The results of simple regression analyses between ID and DTL, and ID and PITF showed statistically sig-

Table 1. Subgroup analysis between MC Only and MC + CSP groups

	MC Only (n = 80)	MC + CSP (n = 26)	p value
Sex			0.109*
Male	18 (22.5)	10 (38.5)	
Female	62 (77.5)	16 (61.5)	
Mean age	55.0 ± 9.2	57.7 ± 9.6	0.357 [†]
Side of craniotomy			0.032*
Rt.	33 (41.2)	17 (65.4)	
Lt.	47 (58.8)	9 (34.6)	
ID of T			0.000 (<0.001) [‡]
(-)	40 (50)	26 (100)	
(+)	40 (50)	0 (0)	
DTL			0.000 (<0.001) [‡]
(-)	53 (66.2)	26 (100)	
(+)	27 (33.8)	0 (0)	
PITF			0.001 [‡]
(-)	60 (75)	26 (100)	
(+)	20 (25)	0 (0)	
Cosmetic deformity (-)	51 (63.8)	26 (100)	0.000 (<0.001) [*]

Values are presented as number (%) or mean ± SD.

**Chi-square* test, [†]*t*-test, [‡]Fisher's exact test.

MC = group with myocutaneous flap only; MC + CSP = group with myocutaneous flap plus reconstruction of the temporalis muscle using a contourable strut plate; ID = inferior displacement; T = the temporalis muscle; DTL = depression along the inferior margin of the temporal line of the frontal bone; PITF = muscular protrusion at the inferior portion of the temporal fossa; Cosmetic Deformity (-) = absence of definite cosmetic deformities of the temporalis muscle

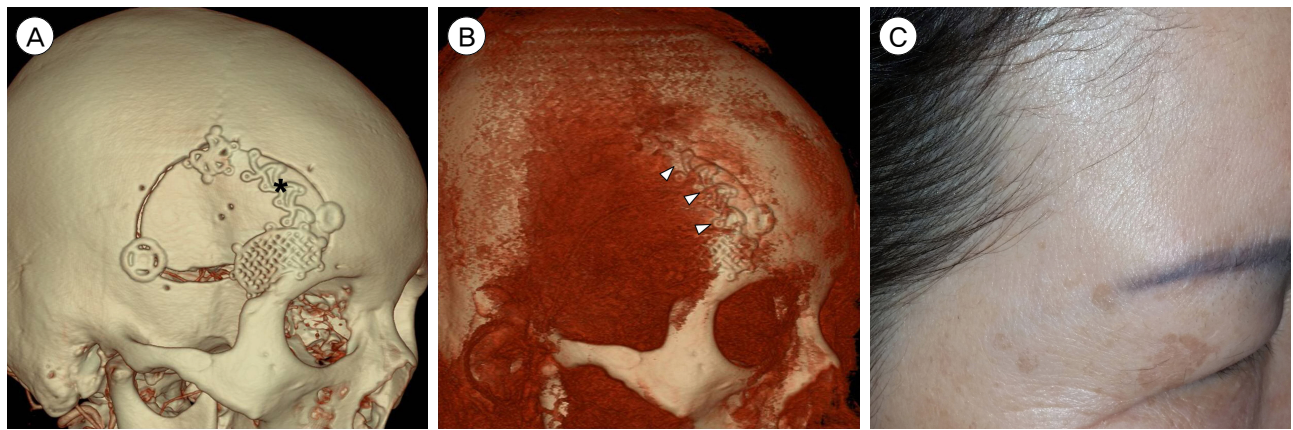


Fig. 5. Three-dimensional computed tomography (CT) scans (A, B) of a patient after reconstruction of the temporalis muscle using a contourable strut plate (CSP) (black asterisk) show anatomical restoration of the temporalis muscle at the temporal line (white arrowheads). A photograph (C) of the same patient shows an outstanding outcome without any deformities of the temporalis muscle.

nificant cause-and-effect relationships ($p < 0.001$ in both), indicating that ID of the temporalis muscle could be a cause of DTL and PITF (Table 2).

There was no occurrence of postoperative wound infection in either group. There were no instrument failures such as screw loosening, displacement of CSP, implant protrusion, or scalp perforation in the MC + CSP group.

DISCUSSION

Reconstruction of the temporalis muscle after PC has been a challenging task for neurosurgeons because there have been no clear solutions completely preventing postoperative deformities of the temporalis muscle. The following causes of temporalis muscle deformities have been suggested: (1) denervation by nerve injury, (2) muscle ischemia by prolonged retraction or interruption of blood supply, (3) direct in-

jury to temporalis muscle fibers, and (4) inappropriate repair of the temporalis muscle to the site of original attachment.⁸⁾¹²⁾¹³⁾¹⁹⁾ Therefore, many surgical modifications of the temporalis muscle reconstruction have been introduced, and the two key points of these modifications to minimize postoperative deformities are (1) preservation of anatomical structures such as the nerves, arteries, and muscle fibers, and (2) restoration of the muscle alignment as similar to the preoperative condition as possible.

The temporalis muscle is innervated by the deep temporal nerves, terminal branches of the mandibular division of the trigeminal nerve, and they course in the deep portion at the medial aspect of the muscle superficial to the periosteum. The blood supply to the temporalis muscle is by the deep temporal arteries and the middle temporal artery. The deep temporal arteries, branches of the maxillary artery, lie superficial to the periosteum, and supply blood to the ante-

Table 2. Simple regression analysis for the cause-and-effect relationships between the variables

Independent variable	Dependent variable	p value
ID of T	DTL	0.000 (<0.001)*
	PITF	0.000 (<0.001)*

*Simple regression analysis.

ID = inferior displacement; T = the temporalis muscle; DTL = depression along the inferior margin of the temporal line of the frontal bone; PITF = muscular protrusion at the inferior portion of the temporal fossa

rior and middle portion of the muscle from the medial side. The middle temporal artery, a branch of the superficial temporal artery, passes through the superficial temporal fascia, and supplies blood to the muscle from the posterolateral side.¹⁾⁸⁾¹⁵⁾²⁰⁾ Injury of these complex structures of nerves and arteries along with muscle fibers can occur during muscle dissection, cauterization for hemostasis, and extensive or prolonged muscle retraction. The muscle damaged by denervation, loss of blood supply, or direct injury gradually necrotizes, undergoes fibrosis and atrophy, and eventually changes to fat tissues.²⁾⁶⁾⁸⁾¹³⁾

Several previous articles reported that making an MC flap has an advantage in the preservation of the frontal branches of the facial nerve, although with a disadvantage in limited exposure over interfascial or subfascial dissection.¹⁴⁾ In the era of minimally invasive microsurgery, with the development of instruments and techniques, a slight limitation of exposure is no longer a problem. Moreover, with just some modifications in the direction of muscle retraction, the operation field can be sufficiently exposed.¹⁶⁾ The advantages of making an MC flap over interfascial or subfascial dissection exist also in the extent of dissection. To make an MC flap, dissection is required only on the medial side of the temporalis muscle. For interfascial or subfascial dissection, extensive dissection on the medial and lateral side of the muscle and transection of the fibers to leave a cuff are required, and the dissected pedicle of muscle is continuously retracted and distorted throughout the surgery. These procedures increase the risk of injury to the muscle fibers, nerves, and arteries. For these reasons, temporalis muscle atrophy is more frequent in interfascial dissection than MC flap.⁶⁾

However, dissection of an MC flap may cause problems from subsequent inferior displacement, or sliding, of the temporalis muscle after detachment of the muscle from the temporal line of the frontal bone (Fig. 2). Unattached temporalis muscle tends to slide following the direction of the muscle fibers during the activity of mastication (Fig. 1). According to the cur-

rent study, 50% of patients who underwent MC flap without adequate reconstruction developed ID of the temporalis muscle, 33.8% showed DTL, and 25% showed PITF. Patients with these temporalis deformities experience cosmetic complexes and functional handicaps. The PITF may cause discomfort when wearing glasses (Fig. 2D-F). Acceptable cosmetic outcomes were achieved in only 63.8% of patients without adequate reconstruction, while the outcomes were dramatically improved by the techniques described in this study (Fig. 5). Therefore, restoration of the muscle alignment is an essential step for MC flap. Multiple methods were introduced for anatomical restoration of the temporalis muscle. Spetzler and Lee¹⁶⁾ introduced a surgical modification that leaves a muscle cuff along the superior temporal line at dissection, and secures the muscle cuff with the dissected temporalis muscle at reconstruction. However, this method again requires transection of the muscle leading to similar problems in interfascial or subfascial dissection. Zager et al.¹⁹⁾ suggested a technique to suture the temporalis muscle around multiple partially advanced microscrews at the temporal line. Other reports also described techniques to suture the muscle to multiple small holes at the temporal line.³⁾⁴⁾⁸⁾ However, these surgical modifications were attempted after subfascial dissection. In addition, multiple partially advanced screws may cause protrusions at the forehead. Making multiple superficial holes and passing threads through them seems too complex and time-consuming.

In this study, reconstruction of the temporalis muscle using CSP after MC flap led to an outstanding outcome. There were no failures of operation due to limited exposure after MC flap. In all cases, anatomical restoration of the temporalis muscle at the temporal line was achieved. Postoperative muscle atrophy and fibrosis were negligible by minimizing the extent of dissection around the temporalis muscle. No cases of DTL or PITF were observed after this technique by preventing ID of the temporalis muscle which was proven to be the causative factor in this study. In addition, this technique is simple and fast. Fixation of

CSP using only two low profile self-tapping screws and suturing over the CSP take less than 5 minutes and are feasible even for beginners.

CONCLUSION

Restoration of the alignment of the temporalis muscle is an essential step after PC. Reconstruction using CSP after MC flap provides an outstanding outcome. This technique is simple and fast, and it provides anatomical restoration of the temporalis muscle at the temporal line and prevents postoperative deformities of the temporalis muscle. Neurosurgeons should be aware of such undesirable cosmetic and functional outcomes after PC, and these deformities must be prevented by adequate reconstruction.

Disclosure

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