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ORIGINAL ARTICLE

Split temporalis muscle flap anatomy, vascularization and clinical applications

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Abstract
Introduction For more than a century, the temporalis muscle has been used for facial reconstructions. More recently, a split temporalis muscle flap elevated on the superficial temporal pedicle has been described, for which the resulting gain of length makes crossing of the midline possible, as well as reconstruction of substance losses exceeding the midline.
Materials and methods Fourteen fresh cadaveric dissections were performed to study the different techniques for splitting the temporalis muscle. Dissections with catheterization and injection of radio-opaque contrasting agent in the external carotid artery were then performed to specify the vascularization of the flap split on the superficial temporal pedicle.
Results The duplication of the superficial temporal pedicle grants greater length compared to that of the deep pedicles, 57 mm versus 40 ($p = 0.036$). The middle temporal artery is capable of ensuring the vascularization, and therefore the viability, of the split flap. From these results, we spoke about the limitations of this study and we have inferred the main indications.

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Introduction

The temporalis muscle is a masticatory muscle, bipennate, located in the temporal fossa of the temporal bone. Vascularization comes from three main pedicles: anterior deep temporal artery, posterior deep temporal artery (both collateral branches of the internal maxillary artery) and the middle temporal artery (a collateral branch of the superficial temporal artery) [11, 12].

The temporalis muscle flap was first described by Golovine [7] in 1898 for reconstruction of the orbit after exenteration. Since then, it has been widely used for this indication as well as for surgery of the skull base and reconstruction of oral cavity and oropharynx defects [1, 4, 6, 13].

In 1995, Kim [8] proposed splitting the temporalis muscle in the plane of the tendinous insertion lamina. This made it possible to increase the length of the flap and reach the midline, thus opening up new directions in cranio-facial trauma and substance loss.

Two types of duplications are possible. Splitting the flap from the deep muscle layer with vascularization ensured by the superficial temporal pedicle; the deep muscular layer finds itself at the distal end of the flap (Fig. 1). The second solution is to split the flap from the superficial layer with vascularization ensured by the deep temporal vascular pedicles, the superficial layer becomes the most distal part of the flap (Fig. 2).

Through dissection of seven fresh cadavers, thus a total of fourteen anatomical specimens, this study initially seeks to compare the length gain obtained according to the type

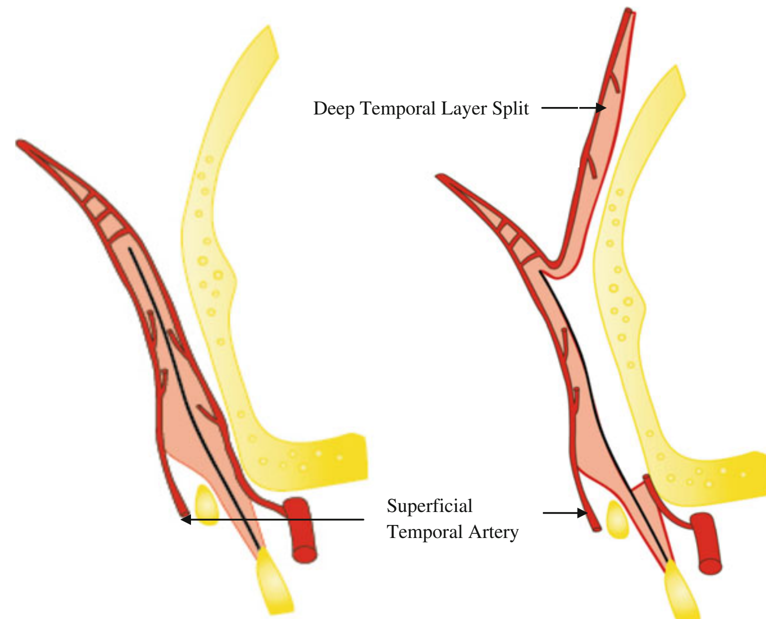

Fig. 1 Schematic sagittal view of the temporalis muscle before and after splitting on the superficial temporal pedicle

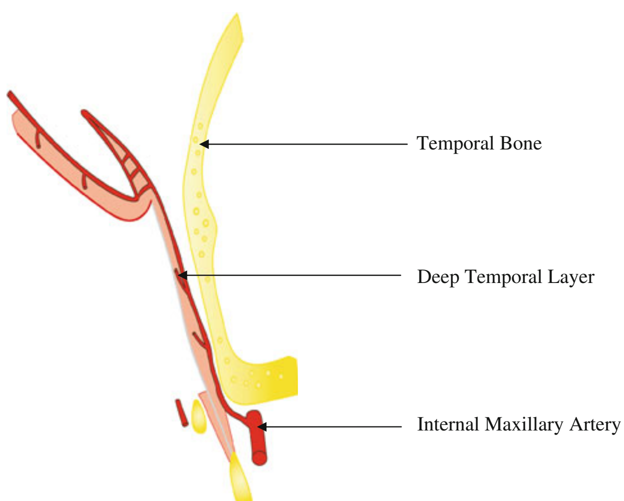

Fig. 2 Schematics of the temporalis muscle split on its deep temporal pedicle

of duplication. We then detail the vascularization of the split temporalis muscle flap elevated on the superficial temporal artery.

Finally, the indications of this split flap will be set out and illustrated with a clinical case of medial craniofacial substance loss coverage with a post-traumatic osteo-meningeal breach.

Materials and methods

The first part of this study aims to compare the length gain obtained depending on the type of split flap. We performed 14 anatomical dissections on 7 fresh cadavers preserved by freezing, and whose age was between 65 and 72 years.

On each cadaver, a split temporalis muscle flap was harvested on the superficial temporal pedicle on one side, and on the deep temporal pedicles on the other side.

For dissection and duplication of muscle on the superficial temporal pedicle, a coronal incision extending to the pretragal area is carried out with a 15 blade.

Dissection passes in a sub-follicular plane above the superficial temporal fascia in order to preserve the superficial temporal vascularization as well as the bulbs of hair follicles. This dissection extends well beyond the surface of the temporalis muscle.

The periosteum is then incised at the superior temporal line. In a subperiosteal plane, the muscle is then removed from the temporal fossa with a stripper up to the deep temporal pedicles which are then ligated and transected as low as possible at the spheno-temporal crest. The nervous pedicles are also ligated during this step. At this same level, the muscle fibers are incised deep across the whole width of the muscle to find the tendinous insertion lamina which is preserved. Elevation of the temporalis muscle is carried out carefully along the tendinous lamina [3] until its upper edge (Fig. 1).

For dissection and duplication on the deep temporal pedicles, the approach and exposure of the temporalis muscle is identical.

The superficial temporal artery is identified, ligated and transected as well as the superficial temporal fascia at the level of the zygomatic arch. The muscle fibers of the superficial layer are transected across the whole width of the muscle up to the tendinous insertion lamina which is preserved. The splitting of the muscle is carried out from the bottom up, stopping at the top edge of the insertion lamina. The deep muscular layer is also released here from the temporal fossa bone, taking care to stay in contact with the bone surface to avoid injury to the deep temporal pedicles (Fig. 3).

Once dissections are performed, accurate measurements are made in millimeters to quantify the gain in length of each split flap. To do this, we measure the distance "zygomatic arch-upper temporal line" and "zygomatic arch-distal end of the split muscle."

These values are drawn for each dissection and an average gain of length is obtained for each type of duplication.

They are then compared by the Wilcoxon Mann–Whitney test.

The second part of our work studies the vascular anatomy of the flap split on the superficial temporal pedicle with a series of four dissections.

On fresh cadavers preserved by freezing, incision and exposure of fascia and superficial temporal pedicle is identical to the first series of dissections. The temporalis muscle is then elevated in a subperiosteal plane and split from the deep layer. A coronoidectomy is performed to release the lower insertion of the temporalis muscle. The superficial temporal artery is dissected in a retrograde manner up to its origin, namely the ending of the external carotid artery into the internal maxillary and superficial temporal arteries. The internal maxillary artery is individualized and ligated. The external carotid artery is transected 3 cm proximal to its ending.

The radiopaque contrasting agent, composed of 100 ml saline (0.9 % NaCl), 40 g barium sulfate powder and 3 g of gelatin powder is heated to 40° and then mixed until homogeneous and is then injected after the catheterization of the external carotid artery. The specimen should then be refrigerated about 24 h (4 °C) for subsequent dissection.

Fig. 3 Temporalis muscle flap split on the temporal superficial pedicle: the flap easily cross the midline (dissection)

After this rest period, the anatomical specimen is placed between two sheets of transparent plexiglass. Conventional mammographic radiographs, 90 mAs intensity and 35 kV voltage, are performed to visualize the vascularization of the two layers of the muscle via the superficial temporal artery (Fig. 4).

Results

The "zygomatic arch-superior temporal line" distance (AZ-STL) corresponding to the length of the temporal muscles is reported in Tables 1 and 2 and shows an average length comparable in both groups: 84 mm for the group on the deep temporal pedicle flap against 86 mm for the group of superficial temporal pedicle flap ($p = 0.58$).

The "zygomatic arch-distally split muscle" length (AZ-DSM) is higher on average in the superficial temporal pedicle flaps (143 mm) against 124 mm on average for the deep temporal pedicle flaps, thus a significant average length gain of 19 mm ($p = 0.018$).

As a result, the average gain in length obtained in comparison with a simple temporalis muscle flap (Fig. 5) is significantly greater ($p = 0.036$) when the dissection is carried out on the superficial temporal pedicle: 57 mm against an average of 40 on a dissection of the internal maxillary pedicle (Table 1).

The split temporalis muscle flap elevated on the superficial temporal pedicle thus provides a greater gain of length than a split temporalis muscle flap elevated on the deep temporal pedicles. This length gain is 19 mm in average.

Regarding the vascular study, radiographs taken after injection of radio-opaque contrasting agent highlight, on all four anatomical specimens, the vascularization of the two layers of muscle of the split superficial temporal flap is observed (Fig. 4).

Indeed, opacified vessels are visualized in the deep muscular layer that is located at the distal portion of the split flap. The vascularization of the deep part of the muscle is achieved through an anastomotic network between the deep temporal pedicles and the superficial temporal pedicle located at the upper part of the muscle, above the tendinous insertion lamina.

Thus, here we show that despite sectioning the deep vascular pedicles and thus the main vasculature of the temporalis muscle, the split muscle maintains its vascularization from the superficial temporal artery.

Radiographs show that our anatomical specimens are perfused over at least three-quarters of their volume (Fig. 4). Only the distal part appears to be less perfused. This finding is in line with the work of Chen [5].

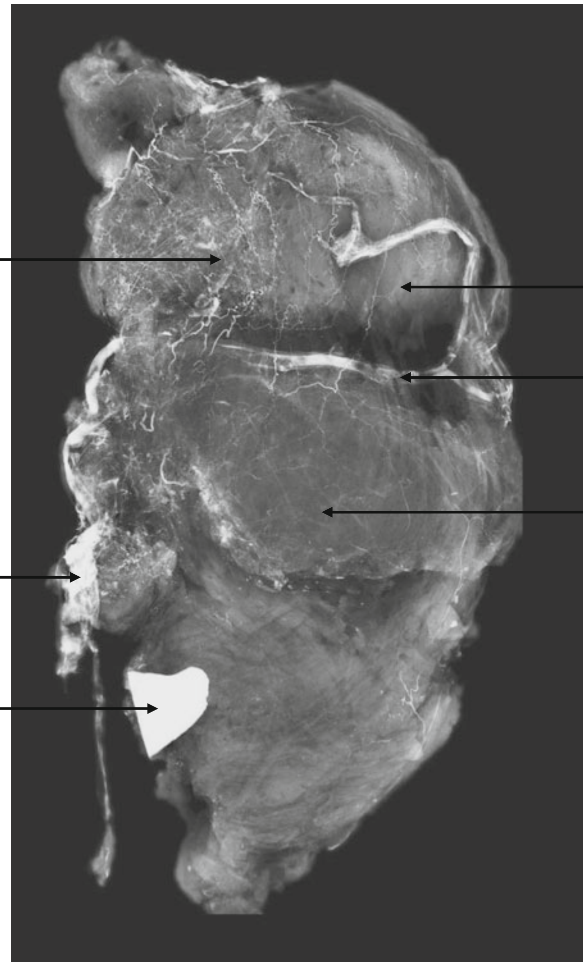

Fig. 4 Radiograph of a temporalis muscle flap split on its superficial temporal pedicle with injection of radiopaque contrasting agent in the external carotid artery, showing the vascularization of three-fourths of the muscle, including the deep muscular layer

Table 1 Lengths obtained from temporal flaps split on the deep and superficial temporal pedicle

Dissection	Split on the deep pedicle			Split on the superficial pedicle		
	AZ-STL (mm)	AZ-DSM (mm)	Win (mm)	AZ-STL (mm)	AZ-DSM (mm)	Win (mm)
1	80	120	40	90	140	50
2	70	120	50	80	140	60
3	80	110	30	80	160	80
4	100	150	50	100	130	30
5	80	120	40	90	140	50
6	90	120	30	80	140	60
7	90	130	40	90	150	60
Average	84	124	40	86	143	57

Discussion

This study has shown that the length of the split temporalis muscle flap is greater when it is pedicled on the superficial temporal vascular pedicle as opposed to the deep temporal pedicle. This difference in length is on average 19 mm in our series of seven dissected fresh cadavers.

When comparing muscle length between a temporalis muscle flap and a temporalis muscle split on its superficial artery, the difference is 57 mm. This difference allows the flap to easily cross the midline, thus broadening its indications.

The vascularization of the split flap is therefore supplied by the sole superficial temporal artery which perfuses the deep muscular layer through its anastomoses with the deep temporal pedicle located beyond the tendinous insertion lamina.

The vasculature of the deep and superficial muscular layers communicates with each other by a dense

Table 2 Summary of our experience with split temporalis muscle flap

	Age (years)	Cause and clinical defect	Type of muscle flap	Percentage of muscle survival (%)	Follow-up (years)
Patient 1	61	Adenocarcinoma Ethmoidal from nose to cerebral parenchyma	Double temporal flap on the superficial pedicle	100	No recurrence of carcinoma or infection after 2 years
Patient 2	52	Substance loss of the middle skull base after severe craniofacial trauma	Double temporal flap on the superficial pedicle	100	No recurrence of infection after 4 years
Patient 3	78	Epidermoid carcinoma of the left forehead and temporal skin up to the periost	Left temporal flap on the superficial pedicle	100	No carcinoma recurrence after 3 years

Fig. 5 Non-split temporalis muscle flap: the flap does not reach the midline (dissection)

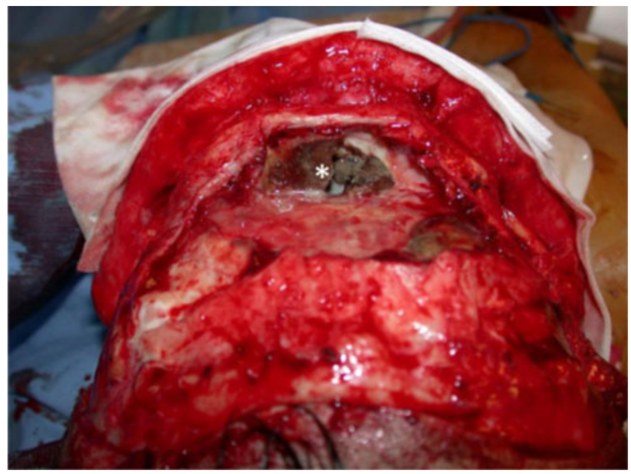

Fig. 6 Fifty-two-year-old patient presenting a craniofacial trauma with a breach in the dura mater and multiple septic complications such as purulent meningitis and empyema. Peroperative visualization of a cranio-sinusal communication

anastomotic network located on the top of the muscle, beyond the tendinous insertion lamina. This vascular arcade begins at the superior temporal line to finish 2 cm below and connects the deep and middle temporal vascular networks.

Our series of four dissections with contrasting agent injection confirm these considerations. It shows a vascularization of three quarters of the flap, in particular in the deep muscular layer.

Through their series of fourteen dissections of temporalis muscle split on the superficial temporal pedicle, carried out on fresh frozen cadavers followed by injection and radiography, Chen et al. [5] have also demonstrated that the superficial temporal artery alone was sufficient to provide 83 % on average of the vascularization of the flap volume in their study.

The fact that our radiographs do not show a complete vascularization of the deep muscular layer is certainly explained by the fact that vascular substitutes that are not found in a corpse exist in a living subject. Indeed, in cadavers, the vessels no longer possess their physiological properties of contractility and elasticity, and the distal arterioles are collapsed, thus preventing a complete vascularization of the flap.

However, our clinical experience with four patients showed excellent vascularization of the entire split flap, without even partial necrosis or scarring problems.

Anatomical variations also exist, with a vascular dominance ensured by either the superficial or deep temporal artery. However, the vascularization of the superficial temporal artery, through the middle temporal artery is invariable, as well as its connections with the deep temporal pedicles. The blood supply of the flap is therefore always ensured as observed in our series and that of Chen et al. [5].

During dissection, the nervous pedicles are sacrificed, the flap is thus denervated. Nevertheless, this absence of

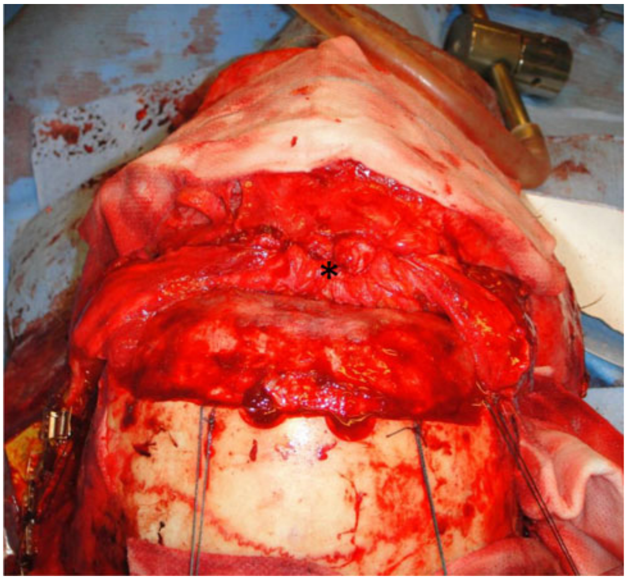

Fig. 7 Peroperative view of both temporalis muscles split on the superficial temporal pedicles and sutured along the midline, thus enabling a tight closure of the communication. This surgery permitted no recurrence after a follow-up of 4 years

innervation is not important because the purpose of this flap is not to provide a functional tissue, as in temporalis muscle transfer for the palliative management of facial paralysis for example, but rather to provide a vascularized muscular tissue to restore a substance loss.

The advantage of this split flap is that it provides a vascularized muscle tissue well beyond the midline at the cranio-frontal region. It allows reconstruction of substance loss of the middle skull base after severe craniofacial trauma [2, 8–10, 14], but also in carcinology where healing must be fast in order to provide radiation therapy on a scarred terrain within 6 weeks after surgery (Figs. 6, 7). This flap is also useful in craniofacial surgery, in infectious contexts where it can assist in obtaining a seal of the facial region (Table 2).

Conclusion

Vascularization of the temporalis flap split on the superficial temporal pedicle is reliable and is provided by the middle temporal pedicle, a branch of the superficial temporal artery.

The length gain obtained is higher than that obtained with a flap split on the deep temporal pedicles and it can easily cross the midline.

This flap should be part of the therapeutic arsenal offered in cases of substance loss of the frontal and craniofacial midline.

Conflict of interest The authors declare that they have no conflict of interest.

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