The anatomical and morphological variations of levator palpebrae superioris muscle and its clinical relevance

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Research Article

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Abstract

The muscle that primarly retracts the upper eyelid is called the levator palpebrae superioris muscle. For eyelid surgery, a thorough understanding of its anatomical and morphological variations as well as the variations of surrounding tissues is necessary. This study conducted on 100 adult orbits in Department of Anatomy, Istanbul University, used an exploratory, descriptive research design. Ethics committee approval was obtained from the Istanbul Medical Faculty Clinical Research Ethics Committee (date:31.03.2021; number:155281). The anatomical and morphological variations of levator palpebrae superioris muscle and its relationship with the superior ophthalmic vein were evaluated. Variations of levator palpebrae superioris muscle were discovered in 11 of 100 orbits. Single (9%), double (1%) and triple (1%) accessory muscle slips were observed. The variations associated with the superior ophthalmic vein were 5%. The origin of accessory muscle slips showed variation as the accessory muscle slips originated either from the proximal or distal half of levator palpebrae superioris muscle. Also the insertions of accessory muscle slips were variable, as they inserted to levator aponeurosis, trochlea, lacrimal gland, lateral orbital wall or the fascia of superior ophthalmic vein. Consequently, levator palpebrae superioris muscle variations are essential for the superior ophthalmic vein as they can directly compress it. Ophthalmologists in particular, practitioners, should be aware of the anatomical and morphological variations of the levator palpebrae superioris muscle.

Introduction

The levator palpebrae superioris muscle (LPSM) is a thin, triangular muscle and is not responsible for the movements of the bulbus oculi. However, during the evolution of vertebrates it became specialized as a retractor of the upper eyelid. Embryologically, it differs from the superior rectus muscle although during embryological development these two muscles share a thickened common epimysium (Sevel 1986). Despite their common origin, the LPSM differs from the extraocular muscles in its unique function in maintaining the position of tarsal plate and blink reflex (Porter et al. 1989). It originates from the margin of the lesser wing of the sphenoidal bone, anterior-superior to the optic canal. Although the muscle's origin is initially a small tendinous structure, it extends distally and becomes wider and flatter. The LPSM loses its muscular feature distally and ends in a wide aponeurosis.

Just below the LPSM, the superior rectus muscle is located. The surfaces of the two muscles are connected by connective tissue called fascia. The fascia between the LPSM and the superior rectus muscle condenses distally, in the superior conjunctival fornix, forming a thick mass. This structure is also defined as a second insertion of LPSM (Hwang 2013). Laterally, the LPSM is seen between the orbital and palpebral parts of the lacrimal gland.

Accessory muscle slips of levator palpebrae superioris

While accessory extraocular muscle slips can be seen in primates, more rarely they can be seen in humans (Park and Oh 2003). They often represent the remnant of lower vertebrates lost in anthropoid

apes and humans. Although human typically has four rectus muscles, an additional accessory lateral rectus muscle is likely to be seen in *Cerco pithecoid* monkeys (Isomura 1981; Schnyder 1984). This accessory muscle slip is innervated by the abducens nerve and is found behind and above the normal lateral rectus muscle. The accessory muscle slips is thought to represent an evolutionary transition in lower mammals and higher primates (Lang et al. 1990). Although some researchers have suggested that this accessory muscle is too small to have a significant effect on the movements of the bulbus oculi, more recent studies have shown that it has the potential to contribute to both elevation and abduction (Boothe et al. 1990). On the other hand, the accessory extraocular muscle slips in human can be seen most frequently in the orbit associated with the superior rectus muscle and LPSM (Kakizaki et al. 2006). They are usually innervated by the oculomotor nerve. The accessory levator palpebrae superioris muscle slips (aLPSM) can be seen arising from both the medial and lateral edges of the main LPSM and extending along its medial and lateral sides. This accessory muscle slips can range from only a few fibers visible histologically to an intact muscle slip that is easily visible on macroscopic dissection. According to the literature, the origin of the accessory fibers can appear at the proximal or distal half of the LPSM. However, the aLPSM insert either to the periorbital fascia which is close to the trochlea, or to the levator aponeurosis, the periorbita, and the fascia surrounding the superior ophthalmic vein. While the exact functions of accessory muscle slips and other accessory extraocular muscles remain unclear, some likely represent developmental anomalies or structures that have preserved evolutionary diversity.

Materials And Methods

Study design

The study was performed on 50 (100 bilateral) adult cadavers (12 female and 38 male) fixed with 10% formalin solution in the laboratory of Istanbul University, Istanbul Faculty of Medicine, Department of Anatomy. Ethics committee approval was obtained from the Istanbul Medical Faculty Clinical Research Ethics Committee (date: 31.03.2021; number: 155281). Both groups of cadavers used in this study—heads that were cut off from their bodies and heads that kept their bodily integrity—were included. The latter was placed on the dissection table in the prone position in order to perform the dissection of anterior cranial fossa.

Anterior Cranial Fossa Dissection

After removing the calvaria with a chainsaw, the brain was removed from the cranial base. With the aid of toothed forceps, the dura mater layers (Fig. 1a) remaining on the anterior cranial fossa were peeled off and removed from the bone structure (Fig. 1b). Using a hammer and chisel, the upper bordering bones of the orbital cavity were removed in to obtain the orbit and the structures within it. With the assistance of pointed surgical scissors, the periorbital fascia was first cut to demonstrate the anatomical structures below the orbital part of the frontal bone. The LPSM and neurovascular structures were then identified after the fat and connective tissue in this region were removed with the help of a toothed forceps and scalpel.

Results

During the dissection, morphological variations of LPSM were detected. Eleven variationts (aLPSM) of dissected 100 orbits were found, where the eight variations had varied forms separation of aLPSM. In addition to morhological variations of LPSM, variations associated with the superior ophthalmic vein were assessed as well. The observed variations (Variations 1–8) were as follows:

First variation: The first variation had an accessory muscle slip (aLPSM) extending from the distal and lateral edge of the LPSM towards the lacrimal gland. The origin of the accessory muscle slip appeared at the distal half of the LPSM. Only one male orbit (left orbit) showed the variation unilaterally (Fig. 2).

Second variation: In the second variation aLPSM was detected that diverged from the distal and lateral edge of the LPSM and extended inferiorly. The defined aLPSM was observed to insert in the lateral wall of the orbit. The origin of the accessory muscle slip appeared at the distal half of the LPSM. Only one male orbit (right orbit) showed the variation unilaterally (Fig. 3).

Third variation: It was observed that 3 accessory muscle slips were separated from the proximal and medial edge of the LPSM. The first aLPSM slip separated from LPSM shared the same insertion with it, while the second and third aLPSM slips were found to terminate in the trochlea. It was observed that the superior ophthalmic vein passed between the first and second accessory muscle muscle slips. The origin of the accessory muscle slips appeared at the proximal half of the LPSM. Only one male orbit (right orbit) showed the variation unilaterally (Fig. 4).

Fourth variation: Accessory muscle slips, which separated from the proximal and medial half of the LPSM, rejoined with LPSM distally and ended in levator aponeurosis. This variation was recorded as the most common aLPSM variant in our study. The origin of the accessory muscle slips appeared at the proximal half of the LPSM. It was seen in a total of 4 orbits (1 female, 3 male), one of which was bilateral (Fig. 5).

Fifth variation: It was observed that the accessory muscle slips, which separated from the proximal part of the LPSM, was inserted in the fascia covering the superior ophthalmic vein. The origin of the accessory muscle slip appeared at the proximal half of the LPSM. In our study, only one male orbit (right orbit) showed the variation unilaterally (Fig. 6).

Sixth variation: The accessory muscle slips separated from the proximal half part of LSPM. It was seen that it terminated in the trochlea of the superior oblique muscle. It was determined that the superior ophthalmic vein passed between the LPSM and aLPSM. The origin of the accessory muscle slip appeared at the proximal half of the LPSM. The single variation was unilateral and observed in the right (female) orbit (Fig. 7).

Seventh variation: Two accessory muscle slips separated from the both proximal and distal half of the LPSM where each accessory muscle slip terminated in the trochlea. The superior ophthalmic vein was seen between the LPSM and the more distally situated aLPSM. While the origin of the first accessory

muscle slip appeared at the proximal half, the second accessory muscle slip originated at the distal half of the LPSM. The single variation was unilateral and observed in the left (male) orbit (Fig. 8).

Eighth variation: The accessory levator palpebrae superioris muscle, which separated from the proximal half part of the LPSM, was found to travel between the branches of the superior ophthalmic vein distally. The origin of the accessory muscle slip appeared at the proximal half of the LPSM. The single variation was observed unilaterally in the left (male) orbit (Fig. 9).

Discussion

Various nomenclatures have been proposed in the literature for the variations of LPSM. The authors refer to 'tensor trochleae' (Budge 1859), 'transversus orbitis' (Bochdalek 1868), 'musculus levator palpebrae superioris accessorius' (Amonoo-Kuafi and Darwish 1998), 'bipartite levator palpebrae superioris' (von Lüdinghausen et al. 1999) for variations seen in LPSM. Lüdinghausen et al. suggested the use of the terms 'levator trochleae' (Sacks 1985; Haladaj et al. 2020) and 'gracillimus' (Kocabıyık 2016; von Lüdinghausen 1999; Whitnall 1921). It has been suggested by researchers that the reported aLPSM variations may be associated with congenital eyelid retraction and congenital blepharoptosis (Amonoo-Kuofi and Darwish 1998; von Lüdinghausen et al. 1999; Yalcin et al. 2009; Sacks 1985; Bartley 1989). In the literature, the incidence of aLPSM-related muscle, which originates from medial side of the LPSM has been reported as 4.3% (Haladaj et al. 2020), 5% (Budge 1859), 8–15% (von Lüdinghausen et al. 1999) and 10% (Yalçın et al. 2009), respectively (Table 1). Also, it has been reported that while aLPSM can be seen unilaterally or bilaterally, the insertion of aLPSM can usually attach in different structures (such as lacrimal gland, trochlea) (Amonoo-Kuofi and Darwish 1998; von Lüdinghausen 1999; Yalcin et al. 2009). Moreover, according to the literature, although aLPSM shares a common origin with LPSM, it bifurcates during its course (Amonoo-Kuofi v Darwish 1998; von Lüdinghausen 1999; Yalcin et al. 2009) and is always innervated by the superior branch of the oculomotorius nerve.

Table 1
Comparison of accessory levator palpebrae superioris muscle variations in various ethnic groups

	Author (Year)	Country	N	(%)
aLPSM	Budge (1859)	Germany	85 (adult cadavers)	5.88
	von Lüdinghausen et al. (1999)	Germany	3 (1 adult cadavers, 2 fetus)	8–15
	Yalçın et al. (2009)	Turkey	60 (adult cadavers)	10
	Haladaj et al. (2020)	Poland	70 (adult cadavers)	4.3
	Nteli Chatzioglou et al. (2022)	Turkey	100 (adult cadavers)	11

aLPSM: accessory levator palpebrae superioris muscle; N: number of samples included in the study

In 1859, Budge (1859) investigated the aLPSM variation in 5 of 85 evaluated orbits. Each of the variations found originated proximal to the LPSM and ended in the sclera, trochlea, or tissues surrounding the muscle. Bochdalek (1868), on the other hand, detected a variation that had not been previously described. Variable muscle slips were seen to extend transversely from the medial and lateral of the LPSM to the orbital wall. He called these variant slips 'transversus orbitis'. In our study, this variation (Fig. 3) was found only in one orbit (1%). Similarly, in the study of Haladaj et al. (2020) the frequency of related variation was reported as 1,43%. In the following years, Macalister (1875) claimed that the LPSM may be fused with the superior rectus muscle at its origin. However, he reported a case that showed no signs of ptosis despite the absence of LPSM muscle. In 1998 Amonoo-Kuofi and Darwish (1998) described a variation in both orbits of a single cadaver, where accessory muscle slips were located between the LPSM and the superior obliquus muscle. They proposed the term ‘accessory levator palpebrae superioris muscle’ (aLPSM). One year later, von Lüdinghausen et al. (1999) revealed that there may be muscle slips between the LPSM and the lacrimal gland. He proposed the nomenclature 'bipartite levator palpebrae superioris' for muscle slips separated from the LPSM. Yalcin et al. (2009) reported that they observed 3 aLPSMs in 60 orbits on the 30 adult cadavers they examined. The reported 3 accesorry muscle slips originated from the lateral and medial sides of LPSM as well as from the origin of the LPSM as a thin and flat muscle.

In our study, the frequency (11%) of aLPSM variation was similar to the frequency reported by von Lüdinghausen et al. (1999), and Yalcin et al. (2009). According to our results, only 1 of 11 aLPSM appeared bilaterally. The remaining 5 aLPSMs were on the right and 4 on the left side. These variations emerged in five different ways:

1. During the course of LPSM, aLPSM slip bifurcated medially (7%). Of the reported seven variations, the 4 were seen to insert to the levator aponeurosis while the 2 variations of the accessory muscle slips terminated at the trochlea. Finally, the last one inserted to the fascia covering the superior ophthalmic vein.
2. Two accessory muscle slips divided from the medial edge of LPSM, one of which shared a common insertion with LPSM and the other part inserted to the trochlea (1%).
3. Three accessory muscle slips divided from the medial edge of LPSM where two of them shared a common insertion, and the remaining one ended in the trochlea (1%). This kind of variation had not been reported before in the literature.
4. Single accessory muscle slip extended from the lateral edge of LPSM towards the lacrimal gland (1%).
5. Single accessory muscle slip extended from the lateral edge of LPSM towards the orbit's lateral wall (1%). Similar variation (1,43%) has been reported by Haladaj et al. (2020) where the aberrant muscle slip resembles an incomplete "transversus orbitis muscle".

Apart from the morphological variations of LPSM, several variations were found especially associated with SOV. According to the classic resources (Standring 2016), the SOV passes under the LPSM and the

superior rectus muscle and reaches the opposite (lateral) side of the orbit. It quits the orbit from the upper part of the superior orbital fissure, close to the lateral rectus muscle. Variations in 5 orbits were observed according to the relationship with the SOV (Fig. 4, Fig. 6, Fig. 7, Fig. 8, and Fig. 9). These identified variations are associated with the SOV and were detected just before passing under the muscles (LPSM and superior rectus muscle). For this reason, it is thought that the accessory muscle slips of the LPSM variations reported in our study may also affect the SOV, especially in pathologies (Graves ophthalmopathy, orbital myositis, etc.) affecting the orbital muscles. This may be caused by direct compression of the muscles (LPSM, superior rectus muscle, or lateral rectus muscle) on the SOV, or by crowding of the orbital apex and enlargement of the superior orbital fissure (Wiersinga et al. 2013).

Additionally, this topographical relationship of superior ophthalmic vein and LPSM is crucial in vascular lesions of the orbit and cavenosus sinus and in direct endovascular accesses to the superior ophthalmic vein. According to the literature, it has been reported that many pathological conditions such as parasellar tumor, carotid-cavernous fistula, dural arteriovenous fistula, intracranial hypertension and hypotension, and Tolosa-Hunt syndrome can be treated using neuroimaging of the superior ophthalmic vein (Tsutsumi et al. 2015). Since direct surgical intervention and cannulation of the superior ophthalmic vein can be difficult, the relationship of the more superficial and proximal part of the superior ophthalmic vein with LPSM was revealed.

In conclusion, in our study, aLPSMs were found in 11 of 100 orbits as a result of the morphological examination. As it is known, LPSM acts as a retractor of the upper eyelid, so the observation of abnormal muscle fibers such as aLPSM can affect the position of the upper eyelids and cause dysfunction. In addition, variations arising from the relationship of LPSM with the superior ophthalmic vein were encountered in only one study in the literature (Haladaj et al. 2020). However, this is crucial for the superior ophthalmic vein as it can be directly compressed due to the variation of the muscle. Consequently, plastic surgeons and ophthalmologists should be aware of the anatomical variations of LPSM both in planning and conducting surgeries on the upper eyelid.

Limitations

The range of ages of the cadavers included in the studies may also be one of the limitations. The orbits, which were analyzed in our study were mostly obtained from cadavers with an average age of 20–80 years. Therefore, whether the observed findings are age-related or not cannot be representative. Also, the lack of retrospective information on cadavers makes it difficult to establish whether variations in this muscle are associated with congenital eyelid retraction or congenital blepharoptosis. This is why we think that research and anatomical studies will continue to be very important in the effort to fill in the gaps in the LPSM's anatomy and morhology knowledge.

Abbreviations

LPSM: levator palpebrae superioris muscle

aLPSM: accessory levator palpebrae superioris muscle

SOV: superior ophthalmic vein

Declarations

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Conflict of Interest

The authors declare that they have no conflict of interest

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Figures

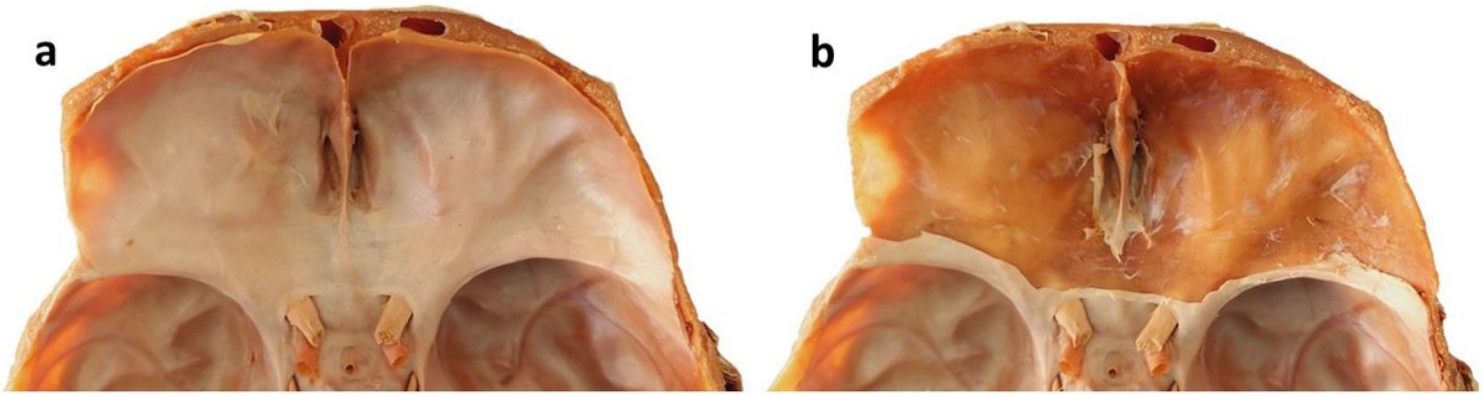

Figure 1

Demonstration of anterior cranial fossa covered by dura mater (a) and after removal of the dura mater (b)

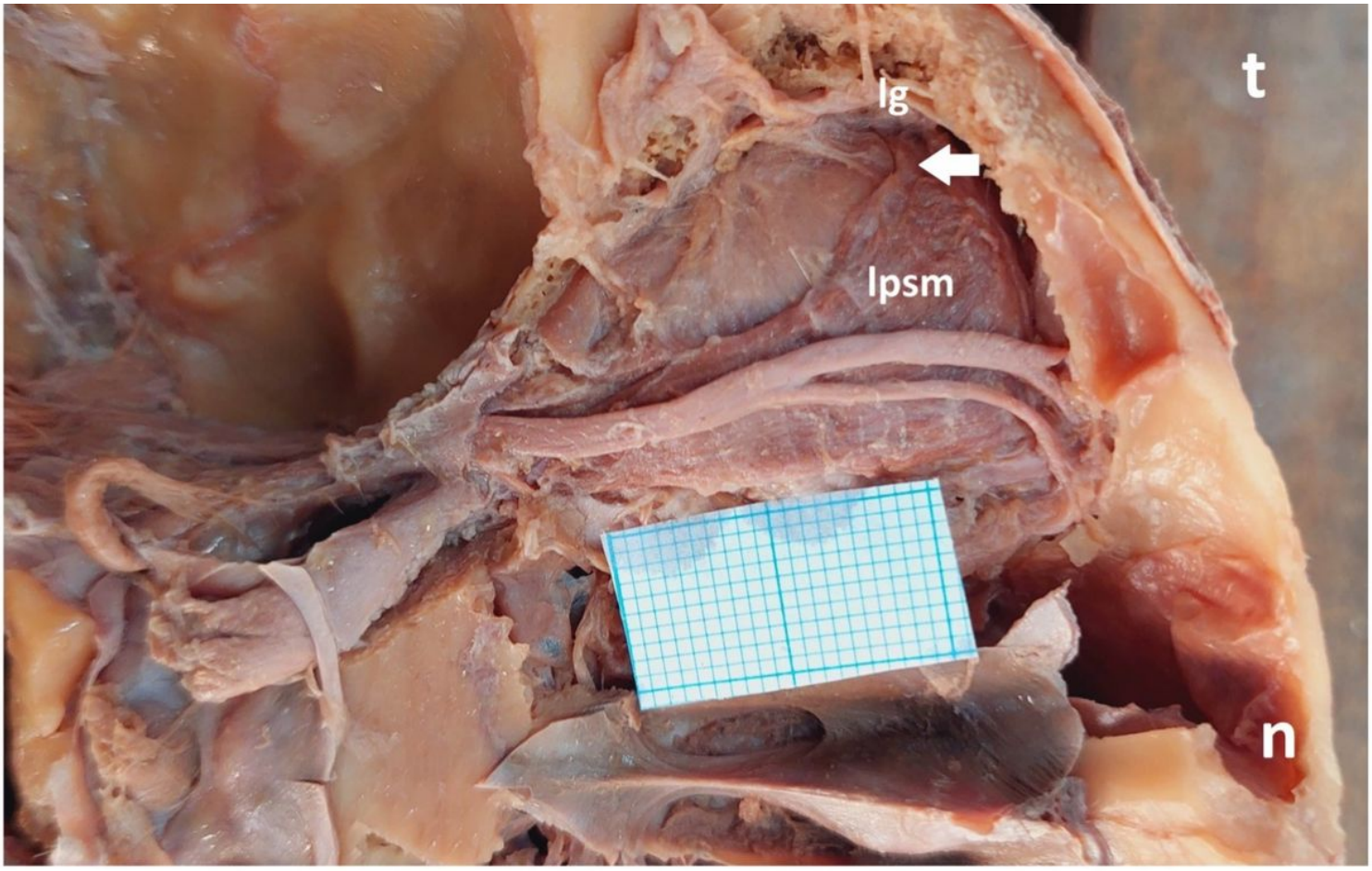

Figure 2

Demonstration of the superior aspect of the left orbit, having laterally situated accessory muscle slip of the levator palpebrae superioris muscle (lpsm). The accessory muscle slip (white arrow) originates from the distal part of the levator palpebrae superioris muscle (lpsm) and inserts to the lacrimal gland (lg), t: temporal; n: nasal

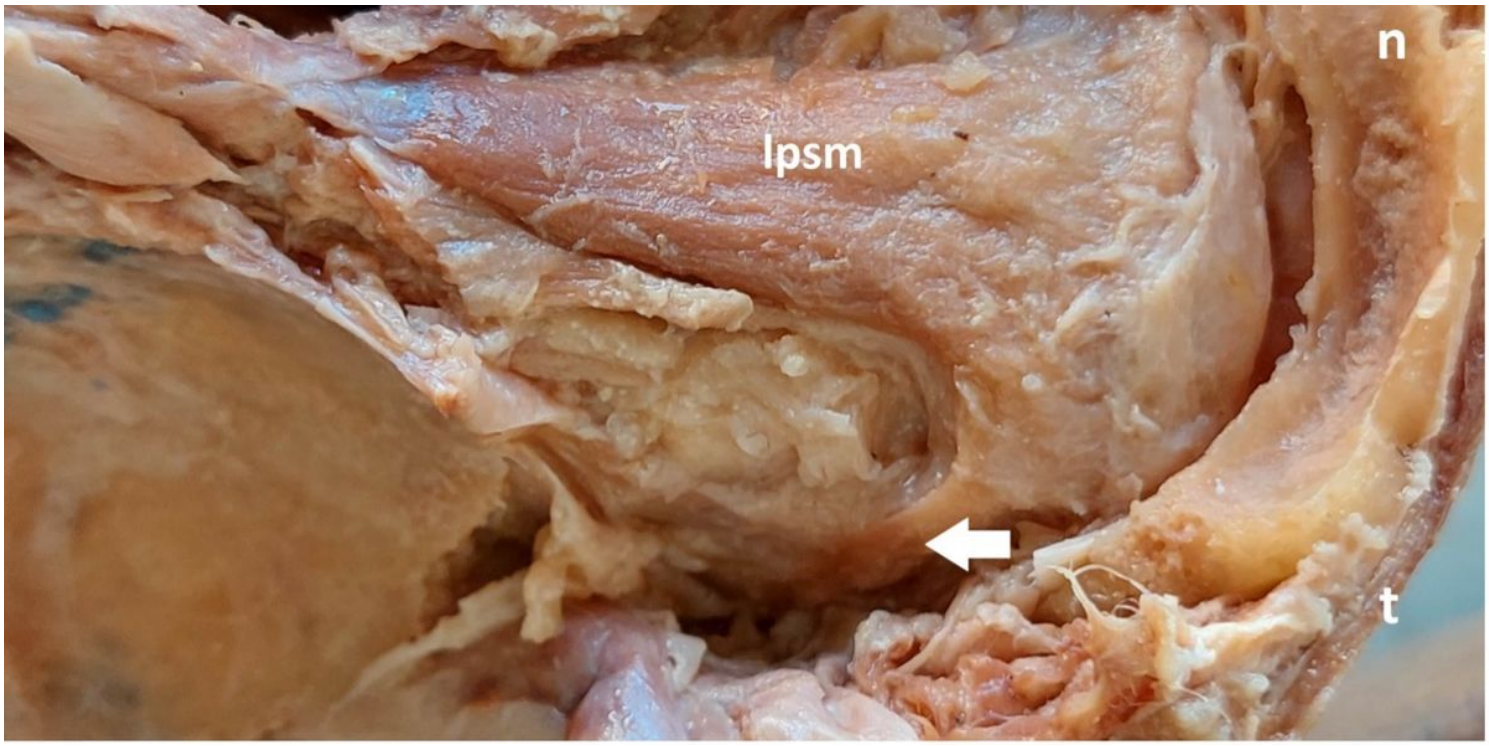

Figure 3

Demonstration of the superior aspect of the right orbit, having laterally situated accessory muscle slip of the levator palpebrae superioris muscle (lpsm). The accessory muscle slip (white arrow) originates from the distal part of the levator palpebrae superioris muscle (lpsm) and inserts to the orbital wall, t: temporal; n: nasal

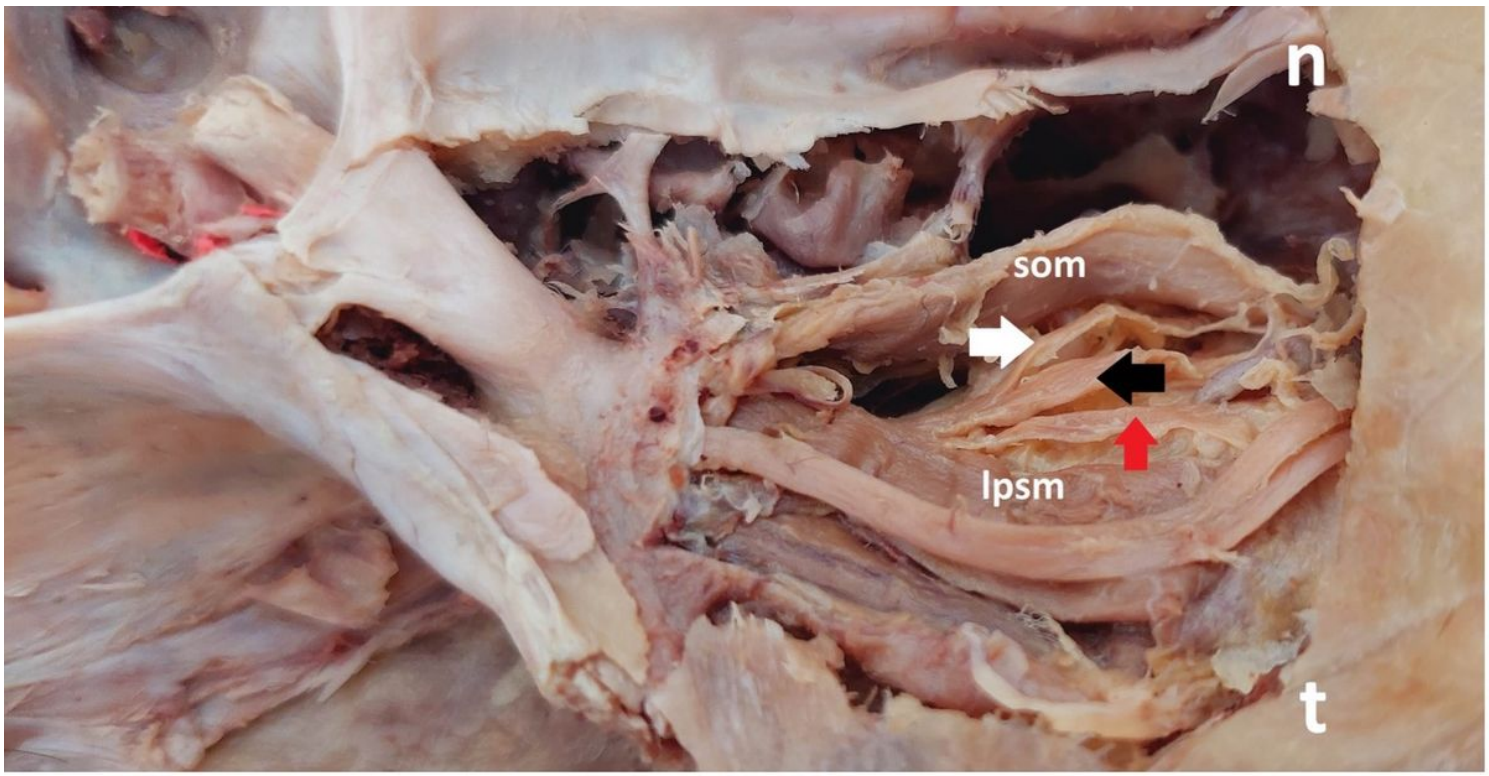

Figure 4

Demonstration of the superior aspect of the right orbit having medially situated muscle slips (white, black, and red arrows) of the levator palpebrae superioris muscle (lpsm). The accessory muscle slips originates from the proximal half part of the levator palpebrae superioris muscle (lpsm). The muscle fibers insert to the levator aponeurosis (red arrow) and trochlea (white and black arrows). Between the accessory muscle slips (black and red arrows), the superior ophthalmic vein is located, som: superior oblique muscle; t: temporal; n: nasal

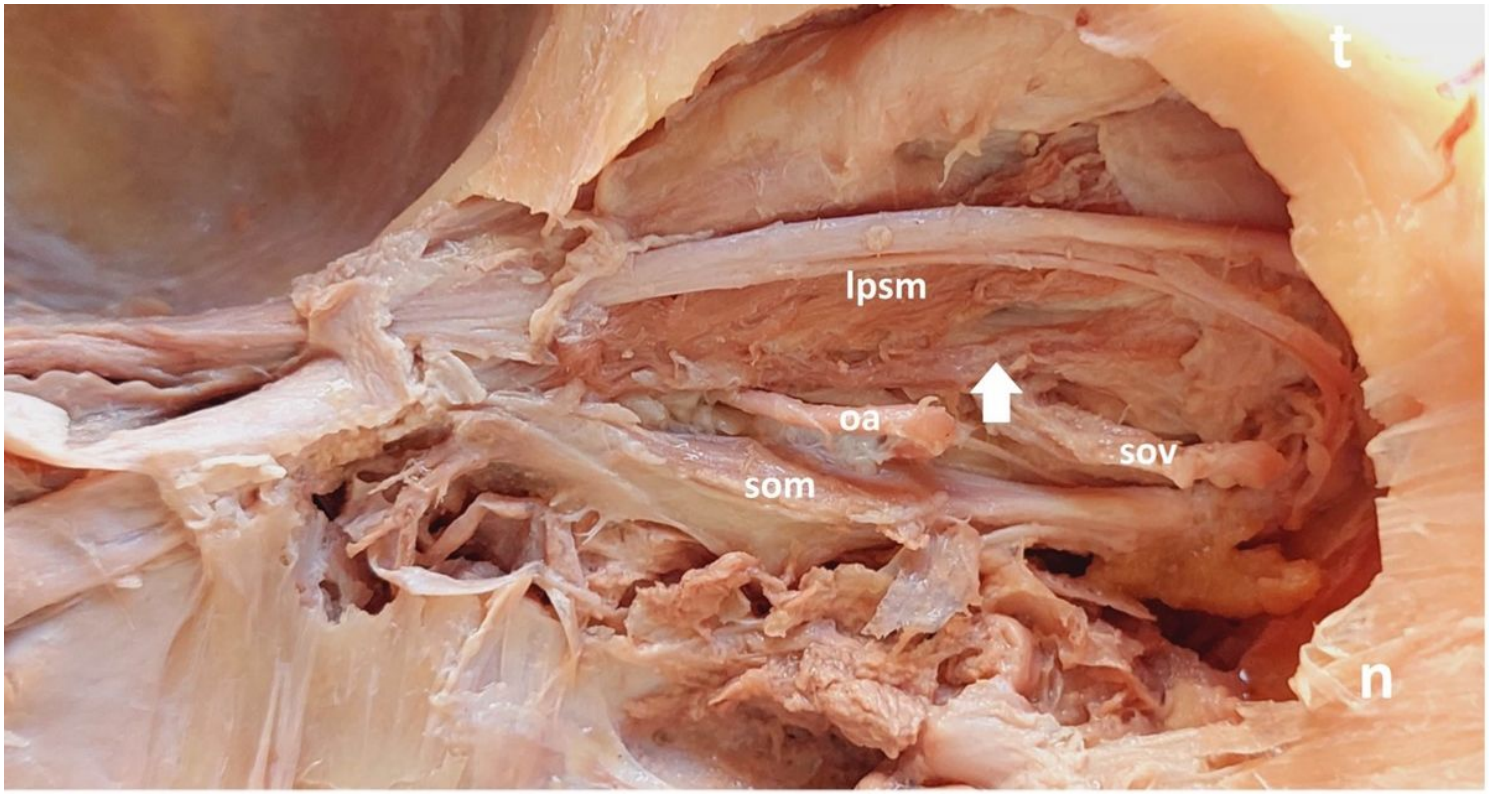

Figure 5

Demonstration of the superior aspect of the left orbit, having a medially situated muscle slip (white arrow) of the levator palpebrae superioris muscle (lpsm). The proximal part of the superior ophthalmic vein (sov) and the ophthalmic artery (oa) travel medially, som: superior oblique muscle; t: temporal; n: nasal

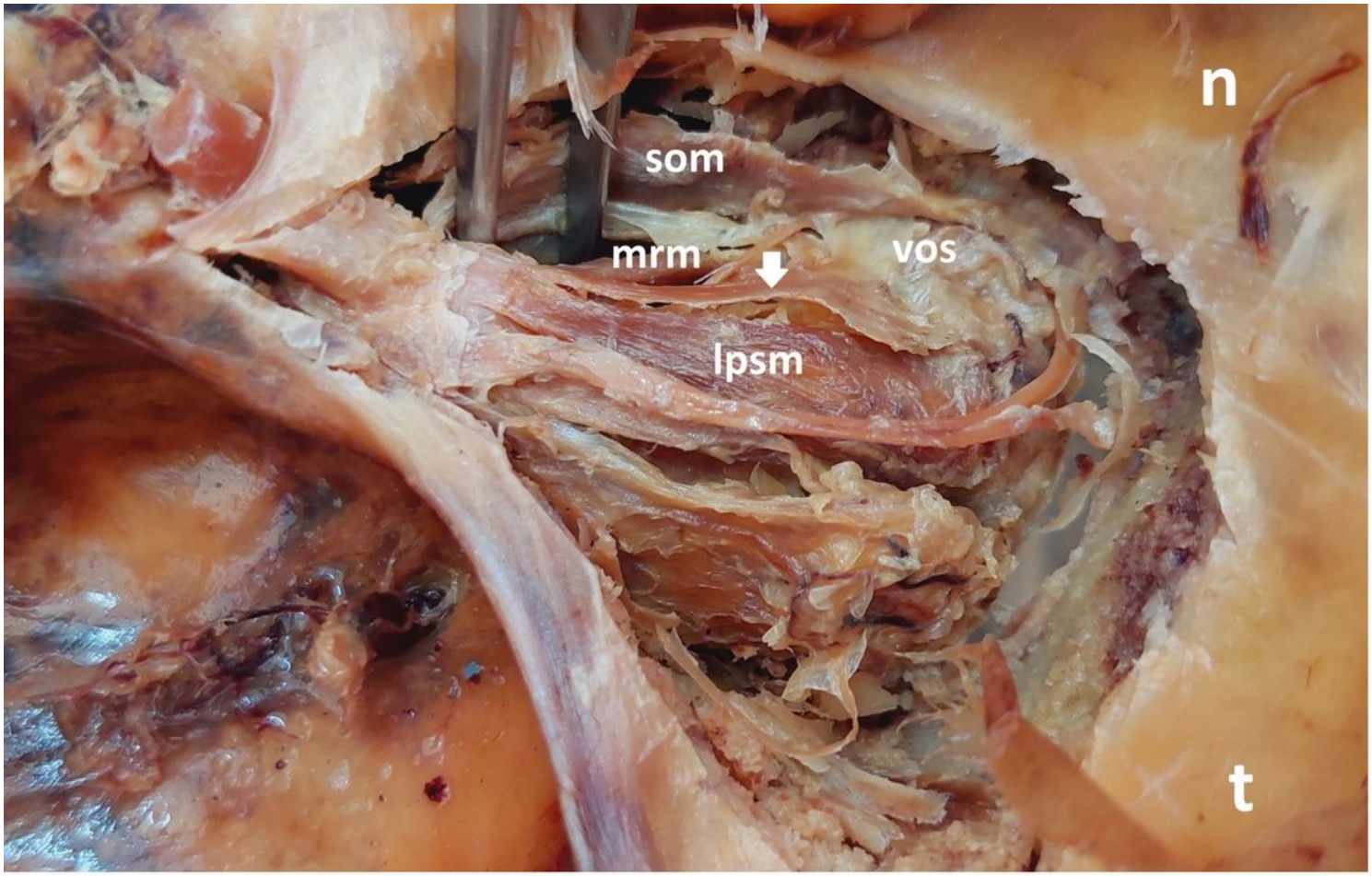

Figure 6

Demonstration of the superior aspect of the right orbit, having a medially situated muscle slip (white arrow) of the levator palpebrae superioris muscle (lpsm). The muscle slip (white arrow) inserts into the superior ophthalmic vein (sov) covered by fascia. It is between the levator palpebrae superioris muscle and superior oblique muscle, t: temporal; n: nasal

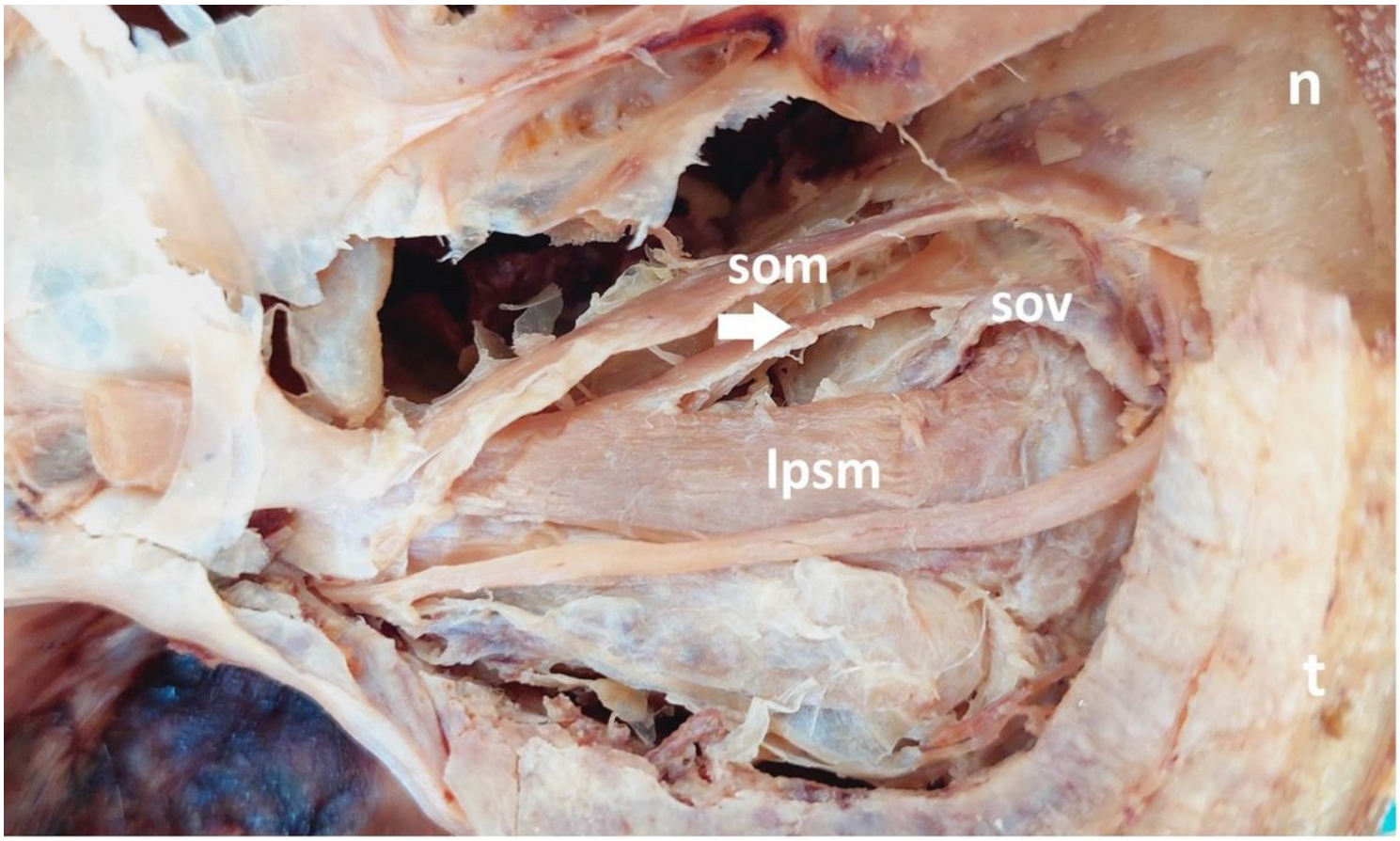

Figure 7

Demonstration of the superior aspect of the right orbit, having a medially situated muscle slip (white arrow) of the levator palpebrae superioris muscle (lpsm). The muscle slip (white arrow) inserts to the trochlea. It is between the levator palpebrae superioris muscle (lpsm) and superior oblique muscle (som), t: temporal; n: nasal

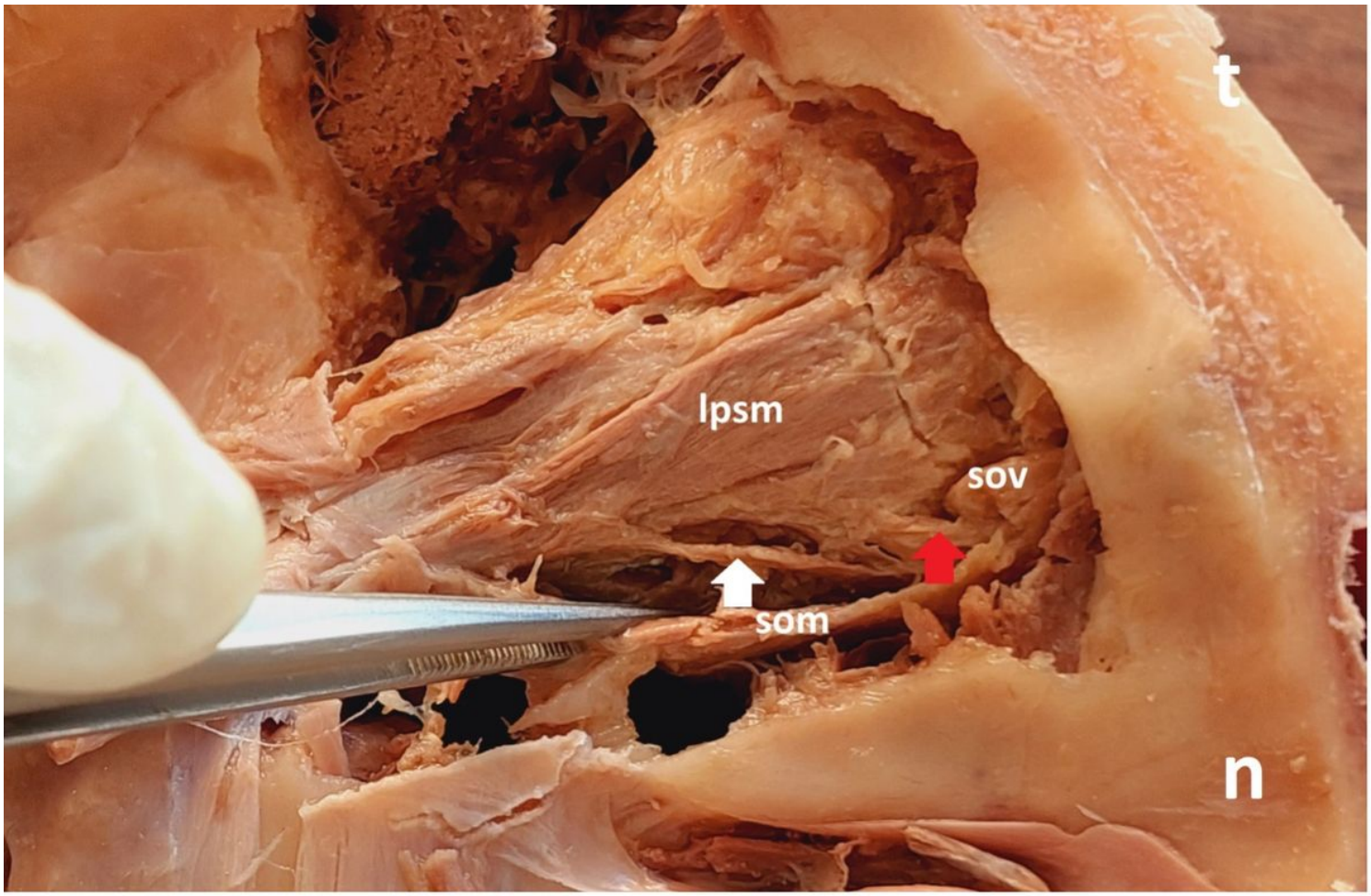

Figure 8

Demonstration of the superior aspect of the left orbit, having medially situated muscle slips (white and red arrows) of the levator palpebrae superioris muscle (lpsm). The first muscle slip (white arrow) originates from the proximal half part and the second (red arrow) from the distal half of the levator palpebrae superioris muscle (lpsm). Between the second (red arrow) and the levator palpebrae superioris muscle (lpsm) the superior ophthalmic vein (sov) is located. Both of the muscle slips (white and red arrows) are between the levator palpebrae superioris muscle (lpsm) and superior oblique muscle (som), t: temporal; n: nasal

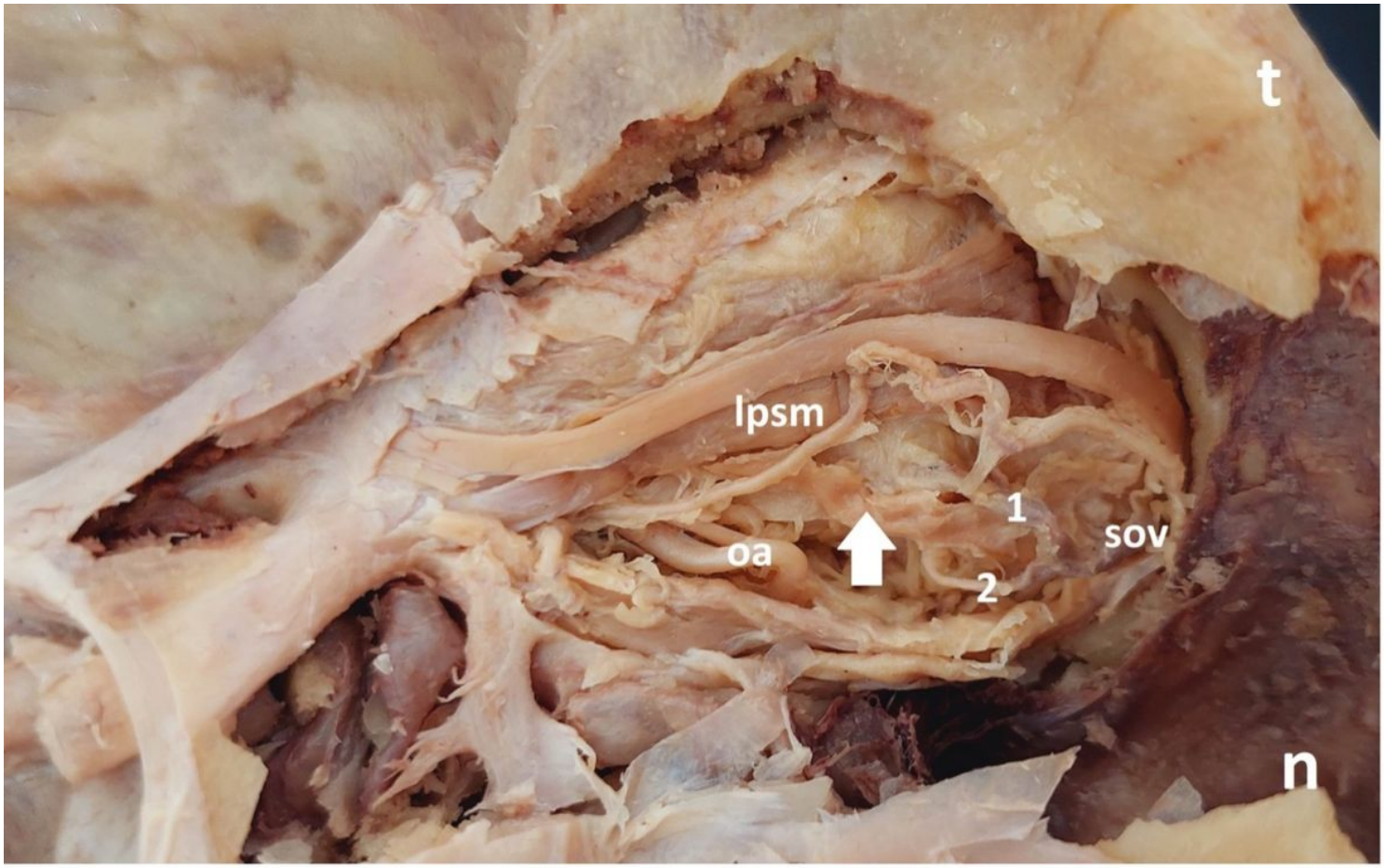

Figure 9

Demonstration of the superior aspect of the left orbit, having a medially situated muscle slip of the levator palpebrae superioris muscle (lpsm). The muscle slip originates from the proximal half part of the levator palpebrae superioris muscle (lpsm) and inserts to the trochlea. The accessory muscle slip (white arrow) is surrounded by the abnormal superior ophthalmic vein (sov), oa: ophthalmic artery; t: temporal; n: nasal