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Periorbital and Intraorbital Studies of the Terminal Branches of the Ophthalmic Artery for Periorbital and Glabellar Filler Placements

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Abstract

Background Filler injections for sunken upper eyelid correction and glabellar augmentation at the orbitoglabellar region need to be performed correctly. Precise knowledge of the emerging sites of all terminal branches of the ophthalmic artery is essential for these procedures to be conducted safely.

Methods The terminal branches of the ophthalmic artery were studied in both periorbital and intraorbital dissections. The aim of this study was to verify the critical positions of the emerging sites at the orbital septum that may act as potential retrograde channels for filler emboli.

Results In the 40 eyes examined, the branches of the ophthalmic artery were found to emerge from four different sites. Two substantial emerging sites were situated on both sides of the trochlea of the superior oblique muscle. These sites were located at the superior part of the medial orbital rim (SMOR) and are alternatively named as the epitrochlear and the subtrochlear emerging sites. The other two sites can be regarded as accessory emerging sites due to the comparably smaller artery. Dissection of the intraorbital region revealed small periosteal branches of the infraorbital artery which coursed anteriorly on the orbital floor to form anastomoses with the lacrimal artery. In other areas of the orbital floor, no branches extended from the infraorbital artery. In front of the lacrimal gland, very minute branches descended and coursed along both margins of the superior tarsus but did not course outside the lateral orbital rim.

Conclusion A danger zone was located at the SMOR, where the ophthalmic branches emerge to form anastomotic channels. Compression at the trochlea guarantees safe injection of filler, reducing the risk of complication.

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Keywords Cadaver · Filler injections · Ophthalmic artery · Sunken eye · Glabellar augmentation

Introduction

Correction of sunken upper eyelids can be performed through either surgery [1, 2] or filler injections [3–5] with focus on the medial side of the depression. However, ocular complications are a serious and undesirable outcome that requires special consideration and treatment [6–10]. Filler injection to correct a sunken upper eyelid, as well as glabellar and nasal dorsal augmentation requires an experienced physician, because injections in this area are highly susceptible to ocular complications [4, 6, 9, 11].

Previous articles have described the anatomy of the ophthalmic artery [12–17], the facial artery [18–20] and the superficial temporal artery [21] in detail. However, none focus on their arterial anastomoses and the possible occurrence of ocular complications from filler injection. This study investigates the emerging sites of all the terminal branches of the ophthalmic artery (TBOA) from both

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periorbital and intraorbital dissections to establish a preventive measure that can be performed during filler placement at the orbitoglabellar region. This region is known as the danger zone for facial filler injection.

Materials and Methods

This study included data from 30 cadavers, 20 soft embalmed and 10 formaldehyde embalmed cadavers with red latex injection into the common carotid arteries. The age range was between 47 and 82 years, with 16 cadavers being female.

Two studies were performed in a successive manner. The first study determined and then simplified patterns of the TBOA which formed periorbital anastomoses, whilst the second study was aimed at searching for intraorbital anastomoses that were not recognized in the first study.

Firstly, the TBOA were studied bilaterally at the emerging sites from the orbital septum around the orbital margins. To find all emerging sites, 40 eyes were studied by conventional dissections, with 20 eyes from 10 formaldehyde embalmed cadavers and 20 eyes from 10 soft embalmed cadavers. All emerging sites were then recorded.

Following this, any other intraorbital anastomotic routes were identified in an additional 10 orbits from another 10 soft embalmed cadavers. In this second study, the orbital contents were approached unilaterally from a superior view. By frontotemporal craniotomy, the superior and lateral orbital walls were chiselled, and the periorbita and part of the retrobulbar fat were carefully removed. All the ophthalmic arterial branches were traced to their terminal anastomoses with neighbouring arteries. Particular attention was paid to identify anastomoses that might be susceptible to filler emboli, such as the intraorbital branches of the infraorbital artery at the orbital floor, branches of the middle meningeal artery at the superior orbital fissure and that of the ethmoidal arteries at the ethmoidal foramina.

Results

Four Emerging Sites of the TBOA

In the 40 eyes dissected, four different emerging sites of the TBOA were identified: two major emerging sites and two minor emerging sites. The two major emerging sites were situated on both sides of the trochlea of the superior oblique muscle (SOM), at the superior part of the medial orbital rim (SMOR). These emerging sites are also referred to as the epitrochlear and the subtrochlear emerging sites (Figs. 1, 2) (this is to avoid confusion with the supratrochlear artery at the glabella). The third emerging site was at the supraorbital notch or foramen, and the last emerging site was located above the lateral canthus. Neither the artery at the emerging site above the lateral canthus or the one at the supraorbital foramen or notch are clinically significant due to the minute size of the emerging arteries. The difference between the epitrochlear emerging site and the supraorbital emerging site was that a tiny artery travelled through the supraorbital foramen or notch together with the supraorbital nerve without a ligament interposition or a bony bridge in the latter, whilst in the epitrochlear emerging site the larger artery pierced the orbital septum caudal to the supraorbital nerve that emerged from the foramen (Fig. 3). Due to space limitation, only an accessory supraorbital artery of 0.1–0.3 mm in diameter could emerge at the supraorbital foramen or notch with the supraorbital nerve. A supraorbital artery with an average diameter of 1.2 mm emerged from the orbital septum below the supraorbital foramen at the epitrochlear or even the subtrochlear emerging site and later joined the course with the supraorbital nerve very near the supraorbital foramen (Fig. 3). Thus, focus was concentrated on the medial orbital rim at the emerging sites above and below the trochlea.

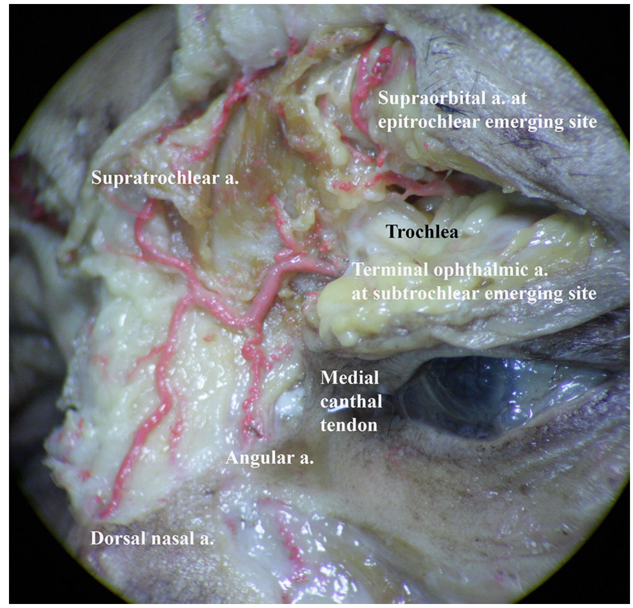

Fig. 1 Two substantial emerging sites are observed on both sides of the trochlea of the superior oblique muscle, later named as the epitrochlear and the subtrochlear emerging sites

Single Trochlear Emerging Site

The artery at the subtrochlear emerging site [1.5 ± 0.5 mm diameter ($n = 40$)] was consistently found in every specimen (100%). The artery diameter reduced to 1.2 ± 0.4 mm ($n = 15$) when the artery exited at the epitrochlear emerging site (Table 1). In the twenty-five

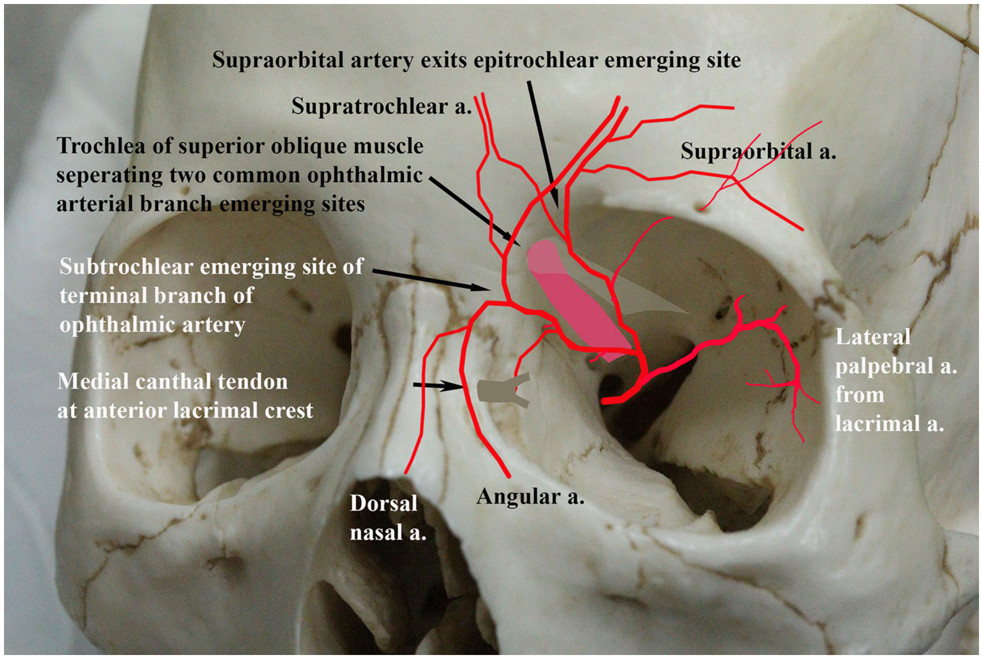

Fig. 2 Position of two substantial emerging sites at the superior part of the medial orbital rim

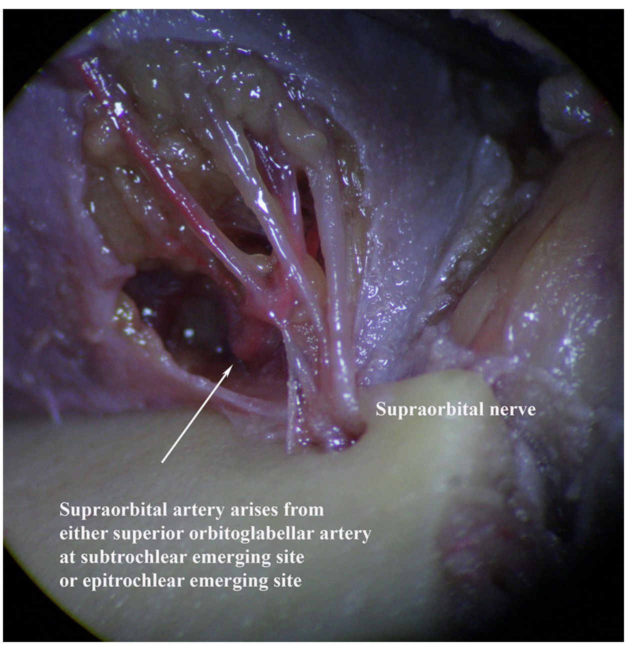

Fig. 3 Superior view of the supraorbital foramen. Supraorbital artery exits the orbit through the orbital septum at the epitrochlear emerging site or as a branch of the superior orbitoglabellar artery at the subtrochlear emerging site and joins the supraorbital nerve after the nerve exits the foramen

specimens in which the epitrochlear emerging site did not exist (62.5%), the artery (1.6 ± 0.5 mm diameter, $n = 25$) emerged from the orbital septum, and divided into two short branches, the superior and inferior orbitoglabellar branches (Fig. 4). The superior orbitoglabellar branch

Table 1 Diameters of the artery depending on types of emerging sites of the terminal branches of the ophthalmic artery (mean ± SD) ($n = 40$)

Single trochlear emerging site ($n = 25$)		
Subtrochlear emerging site		
Both types	1.5 ± 0.5 mm	$N = 40$
Type without epitrochlear emerging site	1.6 ± 0.5 mm	$N = 25$
Type with epitrochlear emerging site	1.2 ± 0.4 mm	$N = 15$
Double trochlear emerging site ($n = 15$)		
Epitrochlear emerging site	1.1 ± 0.4 mm	$N = 15$

curved upwards and laterally along the orbital rim, then further divided into three to five branches in a successive manner around the SMOR as the supratrochlear artery and branches of the supraorbital artery near the supraorbital foramen. The inferior orbitoglabellar branch descended medially across the bony attachment of the medial canthal tendon. The artery divided at the radix into the dorsal nasal and the angular artery on the side of the nose (Fig. 5).

Together, the superior and inferior orbitoglabellar branches demonstrated complicated variations of branching patterns which have important clinical significance. The supratrochlear artery was larger than the supraorbital artery in twelve specimens. In three specimens, it arose from the inferior orbitoglabellar branch and coursed superiorly towards the glabella. The dorsal nasal artery was absent in three specimens. The angular artery was very small in six specimens or was as large as the terminal branch of the facial artery in eight specimens. Among the specimens containing a large angular artery as a continuation of the

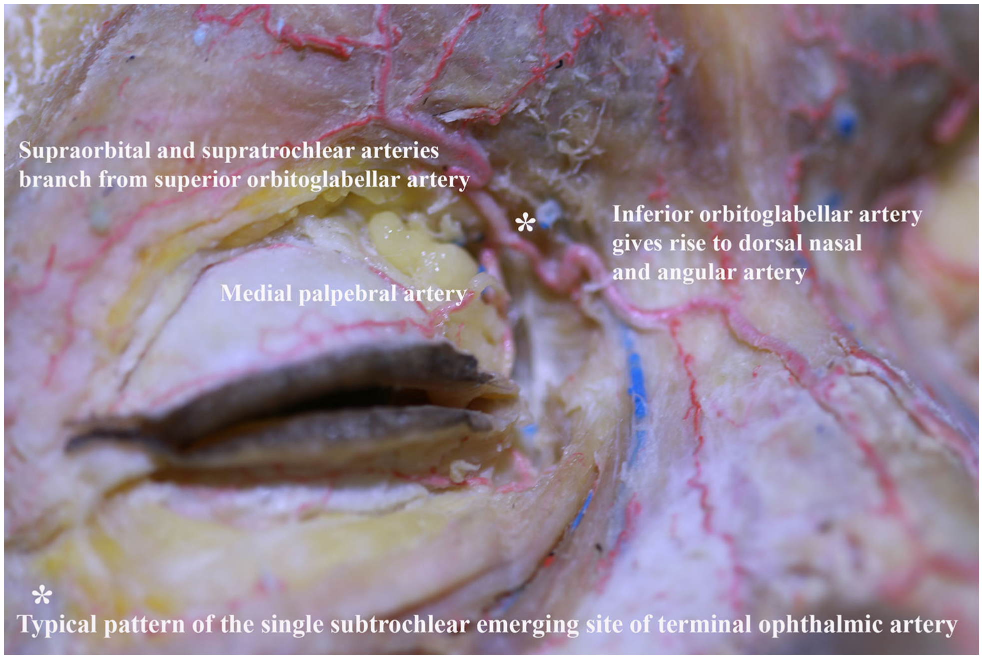

Fig. 4 Single trochlear emerging site. Terminal ophthalmic artery emerges from the orbital septum at the subtrochlear emerging site and then divides into two short branches, the superior and inferior orbitoglabellar branches

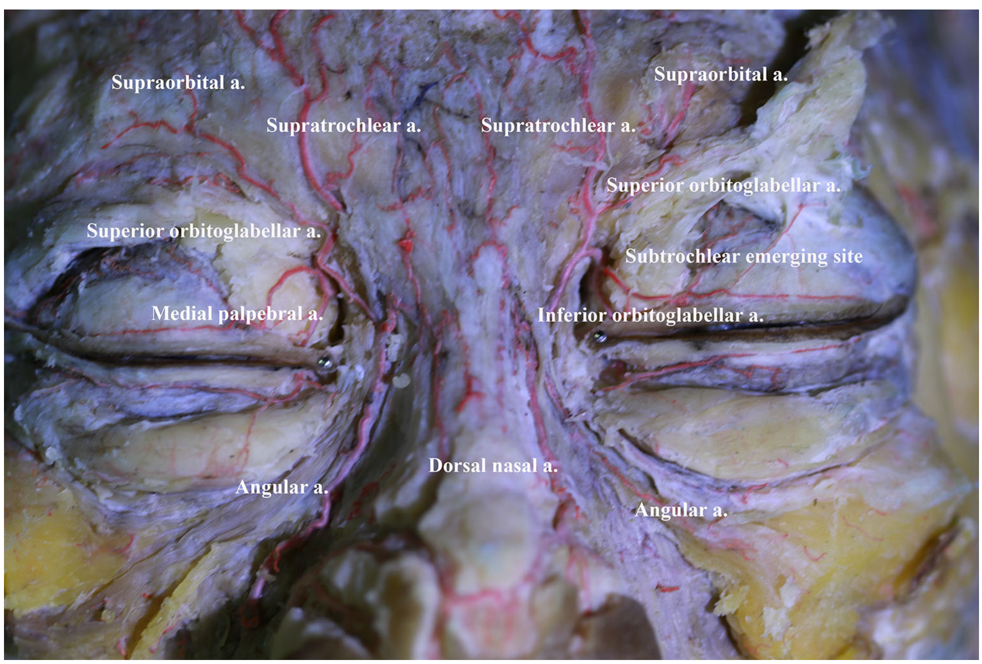

Fig. 5 Superior orbitoglabellar branch divides into 3–5 branches in a successive manner around the superior part of the medial orbital rim as the supratrochlear artery and branches of the supraorbital artery near the supraorbital foramen. The inferior orbitoglabellar branch divides into the dorsal nasal and the angular artery at the side of the nose. The angular artery continues downward as a terminal branch of the facial artery, whilst the dorsal nasal forms an arterial plexus at the nasal tip forming the ophthalmic-facial artery anastomosis

facial artery (as the inferior orbitoglabellar artery), the superior orbitoglabellar artery continued from the angular artery as the terminal branch of the facial artery, and the terminal ophthalmic artery connected at the angular artery as an anastomotic channel.

Double Trochlear Emerging Sites

The artery situated at the epitrochlear emerging site (1.1 ± 0.4 mm diameter) was present in fifteen specimens (37.5%) (Fig. 1). Most were present bilaterally (Fig. 6), but

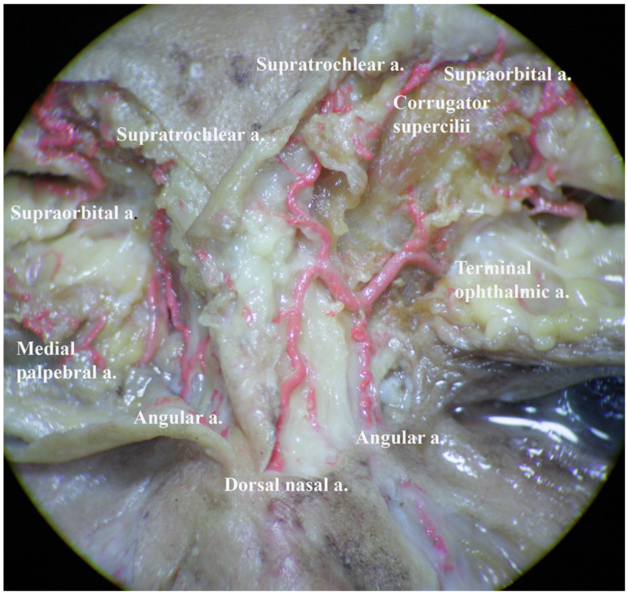

Fig. 6 Bilateral symmetry of double trochlear emerging sites

one was unilaterally. Upon it is exist, the arterial diameter was comparable to that of the artery emerging from the subtrochlear site in the same specimen. It coursed superiorly towards the supraorbital foramen to give off branches in a successive manner as the supratrochlear and the supraorbital artery. In these particular cases, the epitrochlear emerging site held the supratrochlear and supraorbital arteries in a similar way to the superior orbitoglabellar branch mentioned above.

An artery at the supraorbital emerging site was found in three specimens (7.5%). This accessory artery (0.1–0.3 mm in diameter) accompanied the supraorbital nerve in the supraorbital foramen or notch. In seven specimens, this artery was recognized as vasa nervorum running on the surface of the supraorbital nerve.

The lateral palpebral artery at the lateral canthal emerging site (diameter of 0.1–0.2 mm) continued from the lacrimal artery. This artery formed three minute arterial arches with branches of the medial palpebral artery that arose from the terminal ophthalmic artery behind the orbital septum: two on both borders of the superior tarsus and one on the inferior tarsus (Figs. 4, 5). The lacrimal artery had no visible branches that travelled beyond the lateral orbital margin.

Orbital Courses of the Ophthalmic Arterial Branches

The ophthalmic artery divided into main branches and minute posterior ciliary branches around the optic nerve. The artery coursed along the medial orbital wall accompanied by the nasociliary nerve and the superior ophthalmic vein. The anterior and posterior ethmoidal arteries (0.2–0.3 mm diameter) branched off and entered into the corresponding foramina at the medial orbital wall. The ophthalmic artery gave off two main branches (0.4–0.8 mm diameter), the inferior muscular and the lacrimal arteries (Fig. 7).

The posterior ciliary branches (0.1–0.2 mm diameter) ran parallel to the optic nerve towards the neural pole of the globe together with the long, tortious and larger central retinal artery (Fig. 8).

The inferior muscular branch descended towards the inferior rectus muscle, whilst another branch diverged towards the lateral rectus to terminate at the lacrimal gland. Each muscular branch entered the centre of each muscle within the intraconal fat. No arterial branches were present at the outer surface of the muscle.

Each branch that reached the orbital septum medially, subsequently divided as the TBOA. Bifurcation of the ophthalmic artery at the medial orbital wall, in which the two branches ran parallel on both the upper and lower borders of the SOM belly as the epitrochlear and the subtrochlear arteries was found in four specimens, or the artery continued as the subtrochlear terminal artery to the orbital septum in six specimens. In two specimens, a branch of 0.5–0.1 mm diameter arose from the epitrochlear artery to become the accessory lacrimal artery. In front of the lacrimal gland, very minute branches descended and coursed along both margins of the superior tarsus, but did not course outside the lateral orbital rim.

Orbital Branches of the Infraorbital Nerve

In every specimen, the infraorbital artery gave off branches (0.1–0.2 mm diameter) from the infraorbital canal in front of the inferior orbital fissure to the inferior orbital fat. These branches were too small to form anastomoses. In four specimens, periosteal branches of the infraorbital artery (0.2–0.3 mm in diameter) travelled anteriorly on the lateral part of the orbital floor to form anastomoses with the lateral palpebral artery of the lacrimal artery (Fig. 9). In other areas of the orbital floor, there were no branches from the infraorbital artery. No arterial branches entered the orbit from the meningeal artery through the superior orbital fissure.

Discussion

Ocular complications as a result of retrograde route of filler into the ophthalmic artery have been precisely investigated [10]. The facial arteries on both sides usually communicate with the ophthalmic arteries to form the arterial triangles of the danger zone. This danger zone is confined between both cantholabial (medial canthus to nasolabial fold) lines at the

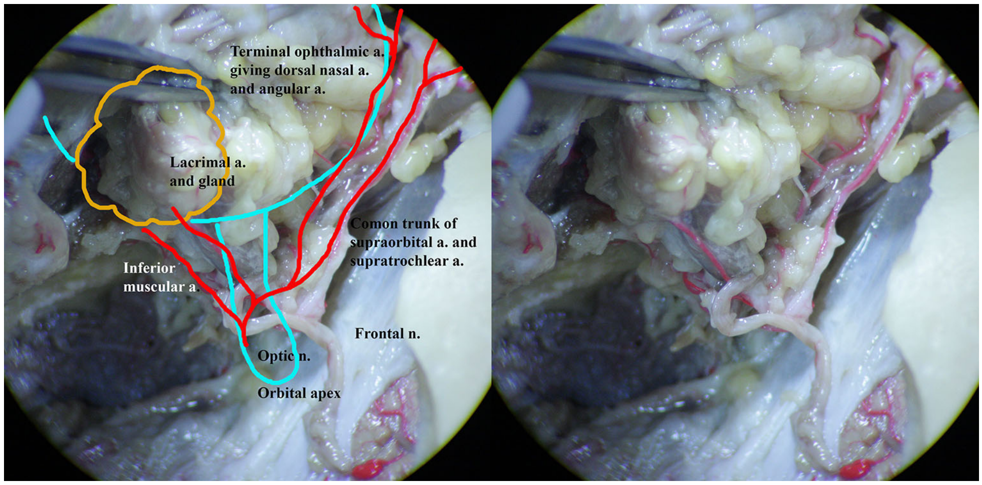

Fig. 7 Superior view of the orbital contents. The ophthalmic artery gives off two main branches of large diameter during its winding course around the optic nerve as the inferior muscular and the lacrimal arteries and then continues along the medial orbital wall. *Left*, illustration; *right*, original photograph

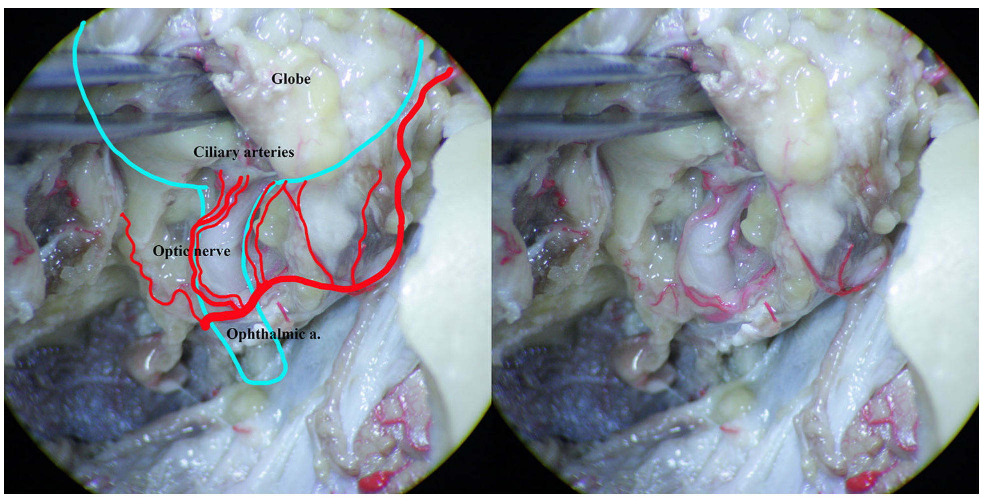

Fig. 8 Superior view of the orbital contents with the optic nerve twisted upward. Many small posterior ciliary branches run parallel to the optic nerve towards the neural pole of the globe, including the tortious central retinal artery travelling within the translucent optic nerve sheath which is removed to display the arterial branches. *Left*, illustration; *right*, original photograph

central face, in which the mouth and nose reside. The safe zones are confined lateral to these lines at the mid and lower face. Migration of filler in the safe zones is an additional concern.

The upper face, especially the area between the interpupillary vertical lines, is defined as the danger zone. The risk of ocular complication increases when injection is close to the emerging sites of the TBOA. Thus, emerging sites from the orbital septum are of particular concern. Our findings conclude that the TBOA emerge at the SMOR, especially at both sides of the trochlea of the SOM. No sizable arteries perforate the orbital septum at the lateral half of the upper lid and the whole lower lid.

Concerning the level of risk, the TBOA has the highest risk of complication and therefore requires only a small amount of filler to cause ocular complications (Fig. 10). The artery that has sizable anastomoses with the TBOA, such as the superficial temporal artery or the facial artery, has a lower risk of complications. A large amount of filler is required to cross the anastomoses and cause clinical symptoms. Surprisingly, the level of risk may be similar to a main arterial branch such as the superior labial artery [22, 23] or the lateral nasal artery compared to that of the facial artery proximal to that main branch.

Clinical Significances of the Trochlea

Through the trochlea is attached behind the orbital septum, this structure is easily palpable just medial to the supraorbital notch above the medial canthus in every

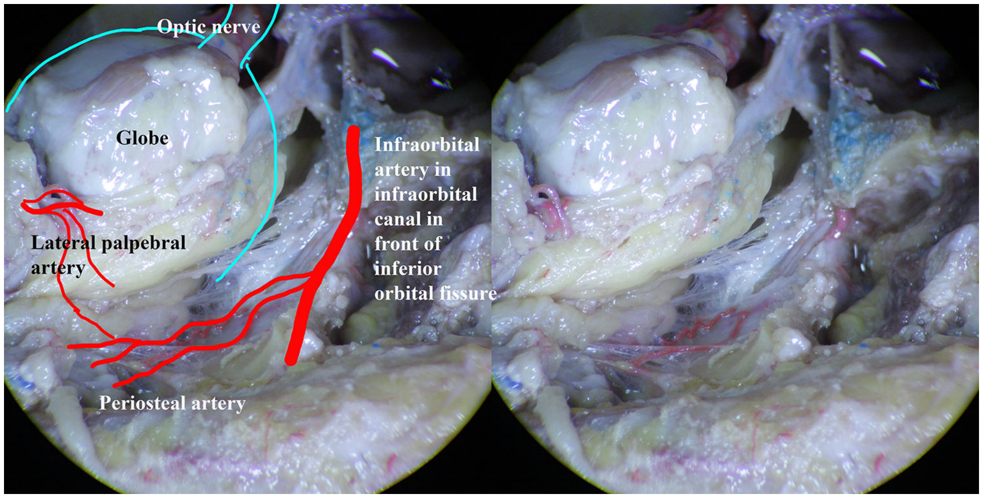

Fig. 9 Lateral view of the orbital floor. Periosteal branches of the infraorbital artery course anteriorly on the lateral part of the orbital floor to form anastomoses with the lateral palpebral branch of the lacrimal artery. *Left*, illustration; *right*, original photograph

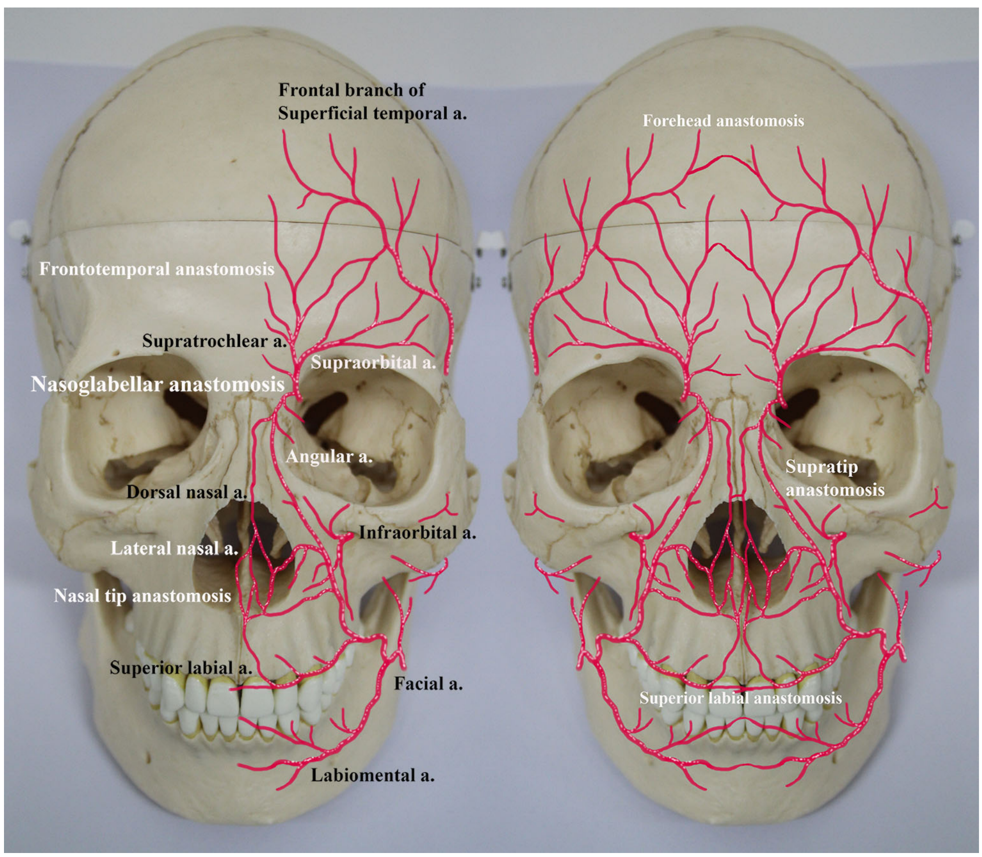

Fig. 10 Unilateral and bilateral anastomoses of the external carotid—internal carotid arterial system of the face through the facial—superficial temporal—ophthalmic arteries. Filler in the terminal branches of the ophthalmic artery leads to more severe ocular complications than the same amount of filler within the facial or the superficial temporal arteries

patient. This differs from the supraorbital notch which can be palpated in only one third of patients. The trochlea is a useful landmark in blepharoplasty procedures, separating the whitish medial compartment from the yellow middle compartment of the superior orbital fat [1]. It also indicates the medial attachment of Whitnall's ligament of the levator aponeurosis [24, 25]. The intercanthal vein and the supraorbital vein usually drain into the superior ophthalmic vein beside the trochlea [12]. We strongly recommended that trochlea compression should be performed, if the aesthetic physician injects filler into the danger zone. If an aesthetic physician would like to concentrate on aesthetic results in which injection into the danger zones is required, an assistant can compress the trochlea bilaterally during each rapid or bolus injection to ensure that no filler escapes into the ophthalmic artery.

Trochlear Compression as a Preventive Measure for Ocular Complications

Prevention of ocular complications is preferable to multiple treatments. Because the arteries at the epitrochlear and subtrochlear emerging sites form significant periorbital anastomoses with the facial and superficial temporal artery, temporary occlusion of the arteries on both sides of the trochlea can completely prevent filler emboli to the eyes. To effectively perform trochlear compression using the non-dominant hand, the injector may approach from the head of the supine patient or from the front as appropriate (Fig. 11). The trochlea is palpable above the medial canthal tendon at the SMOR. Trochlear compression should be performed against the bony orbital rim. Entry of the cannula is recommended at the midline glabella. The tip is advanced in a gentle fashion towards the sunken eye depression. The canula tip should be felt at the depression by the non-dominant hand. Compression to temporarily obliterate the TBOA can then be performed during repeated retrograde injections in a fanning pattern (Fig. 12). If the cannula glides along the bony curve, it can pass through the corrugator supercilii deep from the supratrochlear artery. This technique will place the filler at the space between the depressor supercilii and the orbital septum both lateral and inferior to the corrugator supercilii (Fig. 12). The protective procedure of trochlear compression can push down the globe, the medial fat compartment and the orbital septum away from the cannula tip. Although the possibility of vascular injury still exists, retrograde injection of filler into the ophthalmic artery is impossible, because the injection pressure cannot overcome the occluded luminal pressure.

Injection Techniques at the Danger Zone

In nasal and glabellar augmentation and sunken upper eyelid correction, injections of filler around the TBOA are required, in which a suitable technique is essential [4, 5]. Two injection techniques are known to avoid ocular complications: very superficial injections and deep injections at the pre-periosteal plane. Superficial injection is difficult to perform due to the possibility of surface irregularity. Direct injections using a sharp needle may be recommended [4]. A novice aesthetic physician lacking precise knowledge of

Fig. 11 Right and left eye injections near terminal branches of the ophthalmic artery using midline glabellar entry site with trochlear compression. Lower pictures depict a finger of the non-dominant hand compressing at the superior part of the medial orbital rim from the front (**a**) and from above (**b**). Bilateral compressions during each dangerous injection are recommended to ensure safety

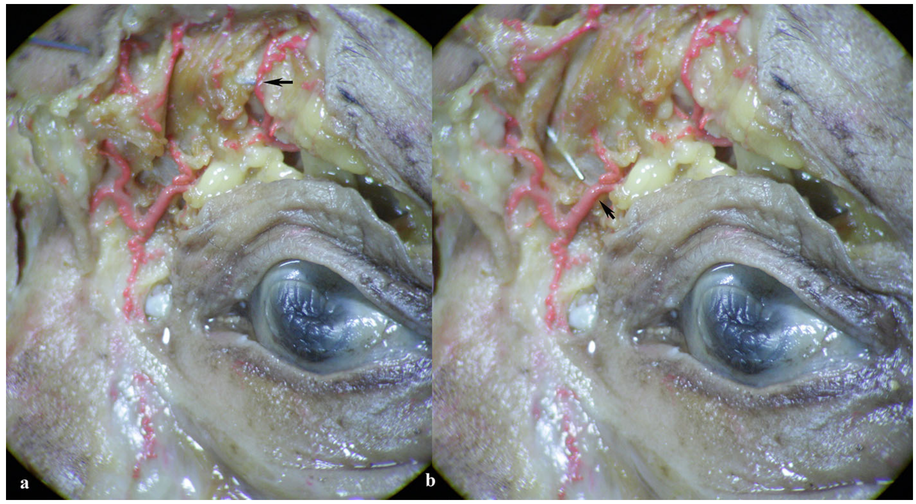

Fig. 12 Cannula passes horizontal and deep to the corrugator supercilii muscle belly [*arrow head* in **a** and passes obliquely superficial to the corrugator supercilii origin but deep to the procerus muscle and the depressor supercilii muscle (**b**)]

the TBOA may encounter ocular complications if more product is injected into this area. Deep pre-periosteal injection entering at the midline glabella with trochlear compressions is an appropriate technique recommended to reach the upper eyelid depression.

Essential Injection Skills

Superficial injection is safest, but physicians are usually faced with subsequent irregularities and the Tyndall effect [26]. Whilst injection in the deep subcutaneous layer and the SMAS (superficial musculoaponeurotic system), this could run the risk of intravascular cannulation [11]. Retrograde injection involving small aliquots of filler is the standard technique used to add volume whilst acquiring a smooth elevation [27]. Novice physicians may have difficulty controlling the amount of injected filler, especially in stiff or scar tissue. A large bolus may be accidentally injected when the cannula passes from stiff tissue to loose fat. In this instance, the physician cannot rely on visual appearance and/or palpation of the product. Thus, practice of regular small injections along the retrograde tract is suggested. In a similar situation, a sizable artery within a stiff tissue can simulate a pocket or a less-resistant channel in which the cannula can accidentally pierce both arterial walls. A bolus may be injected when the physician feels a decrease in resistance when the cannula tip resides within the arterial lumen. This risk increases when deep bolus injection is planned or the towering technique is used. Manual compression of the TBOA can ensure safe injection during these techniques.

The non-dominant hand is usually used in stretching or elevating the skin to allow possible advancement of the cannula. It also helps to mould and distribute filler evenly,

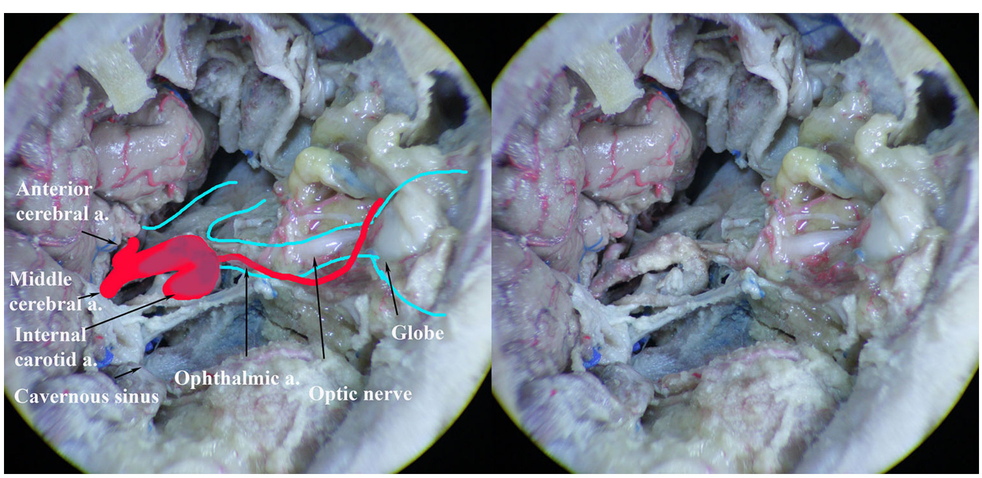

Fig. 13 Supero-lateral view of the skull base. The high chance of eye complications is closely related to the incidence of cerebral embolism with neurological symptoms based on the fact that the ophthalmic artery is very close to the cerebral arteries. If the filler reaches the central retinal artery, it can retrogradely advance a very short distance to enter the internal carotid artery that supplies the cerebral cortex. *Left*, illustration; *right*, original photograph

as well as roll the tissue over to facilitate injection. With enough practice, the aesthetic physician can utilize bilateral trochlear compression using the non-dominant hand during high risk injection.

Although this article recruited a limited number of samples, the occurrence of common patterns of the TBOA can still be obtained. This article reveals the most dangerous area for injection resides at the SMOR, in comparison to other periorbital areas. This study suggests an alternative entry site of cannula injection at the glabella based on an anatomical view point. Different opinions on the most appropriate entry site, such as the lateral brow entry site or the lateral canthal entry site, can arise depending on personal favourites and experiences [3–5].

Finally, the high risk of eye complications is closely related to the incidence of cerebral embolism with neurological symptoms. This is based on the fact that the ophthalmic artery is very close to the cerebral arteries (Fig. 13). If the filler reaches the central retinal artery, it can advance retrogradely (roughly a distance of 1.5 cm), to enter the internal carotid artery that supplies the cerebral cortex. Orbitoglabellar depression at the sunken upper lid requires extreme caution when one performs filler injections.

Conclusion

The danger zone is situated at the SMOR, where the TBOA emerge or anastomotic channels exist. Trochlear compressions guarantee safe filler injections.

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Compliance with Ethical Standards

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

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