A case series: 3-dimensional computed tomographic study of the superior orbital vessels: Superior orbital arcades and their relationships with the supratrochlear artery and supraorbital artery

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Background: Vascular complications from periorbital intravascular filler injection are major safety concerns.

Objective: To thoroughly describe the superior orbital vessels near the orbital rim and propose considerations for upper eyelid and forehead injections.

Methods: Fifty-one cadaver heads were infused with lead oxide contrast media through the external carotid artery, internal carotid artery, and facial and superficial temporal arteries. Computed tomography (CT) images were obtained after contrast agent injection, and 3-dimensional CT scans were reconstructed by using a validated algorithm.

Results: Eighty-six qualified hemifaces clearly showed the origin, depth, and anastomoses of the superior orbital vessels, which consistently deployed 2 distinctive layers: deep and superficial. Of all hemifaces, 59.3% had deep superior orbital vessels near the orbital rim, including 44.2% with deep superior orbital arcades and 15.1% with deep superior orbital arteries, which originated from the ophthalmic artery. Additionally, 97.7% of the hemifaces had superficial superior orbital arcades, for which 4 origins were identified: ophthalmic artery, superior medial palpebral artery, angular artery, and anastomosis between the angular and ophthalmic arteries.

Limitations: The arterial depth estimated from 3-dimensional CT needs to be confirmed by standard cadaver dissection.

Conclusion: This study elucidated novel arterial systems and proposed considerations for upper eyelid and forehead injections. (J Am Acad Dermatol 2021;84:1364-70.)

Key words: 3-dimensional computed tomography; filler injection; sunken upper eyelid injection; superior orbital arcade; superior orbital vessel; supraorbital artery; supratrochlear artery.

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The eyelid is one of the most exquisite structures, and it plays an important role in facial esthetics and function.[1] The upper eyelids, with adequate fullness and sharp, clear eyelid folds, are important features of a beautiful and young face.[2,3] A sunken, hollow upper eyelid makes a person look older, tired, and gaunt.[4] Eyelid aging is affected by many factors, including gravity, loss of fatty tissue, and ultraviolet radiation. Fat atrophy can also lead to a sunken deformity of the upper eyelid.[5,6] In addition, excess fat removal during blepharoplasty can also lead to eyelid hollowness.[6-8] The treatment of sunken upper eyelids requires a sufficient amount of soft tissue in the upper eyelids. Common methods for correcting this deformity include autologous fat graft, dermofat graft, fascia-fat graft, local tissue transfer, and dermal filler injection.[9-12] Currently, soft tissue filler injection is a popular treatment for upper eyelid depression. Although the outcomes are immediate and effective, the complications can range in severity from hematoma and ptosis to blindness and even cerebral infarction.[13-15] Therefore, a comprehensive understanding of the arterial variations in the upper eyelids is of great importance for injections to correct sunken upper eyelids.

CAPSULE SUMMARY

- Three-dimensional computed tomography is an efficient and reliable technique to validate complex facial vascular anatomy.
- Clinicians may predict the vascular patterns near the orbital rim and help propose considerations for upper eyelid and forehead injections. Further research is required to apply these findings to clinical practice.

Traditional cadaver dissection can provide a preliminary understanding of the blood vessels, but the location of the vessels may be disrupted during dissection. Three-dimensional (3D) computed tomography (CT) is an efficient and reliable imaging technique that has been widely used to visualize complex human vascular anatomy.[16-21] Although some researchers have described preliminary 3D CT mapping of individual arteries in the face, including the periorbital region, the superior orbital vessels have not been systematically screened. Thus, by using high-throughput postmortem 3D CT of 86 cadaver hemifaces, this study shows the location, course, and anastomosis of the superior orbital vessels near the orbital rim. The results provide guidance for correcting sunken upper eyelids, thereby reducing the adverse events associated with injections.

METHODS

Fifty-one fresh cadaver heads of Chinese Han individuals were voluntarily donated from the Guangdong Second Provincial General Hospital of Guangdong Province (Guangzhou City, China), including 20 men and 31 women. The mean age of the cadavers was 37 ± 6 years (range, 28-62 years). This anatomic study conforms to the Cadaver Dissection Regulations of the China Ministry of Health. The CT contrast process was modified slightly from a reported method.[22] Forty grams of lead oxide (Shantou Guanghua Chemical Co, Ltd, Shantou City, People's Republic of China) was stirred continuously and mixed with 5 mL red dye and 100 mL latex. The suspension was then filtered to remove lead oxide particles.

The external carotid arteries (ECAs) of 25 cadaver heads were injected with sufficient lead oxide media. Sufficient contrast media was injected through the ECAs and internal carotid arteries (ICAs) in 16 cadaver heads, and the facial and superficial temporal arteries were injected sequentially in the other 10 cadaver heads.

After each arteriography injection, the same 64-row spiral CT scanner (Philips Brilliance 64 scanner; Philips Healthcare, Cleveland, OH) was used under the same conditions: 120-kV tube voltage, 250-mA effective tube current, data acquisition trigger of 140 Hounsfield units, 500 × 600–mm field of view, and 1024 × 1024–pixel slice size above the baseline. The thickness of the section is 0.8 mm, and the increment is 0.4 mm.

In the subsequent data analysis, 86 qualified hemifaces from 51 fresh cadaver heads were collected, and 16 hemifaces (from 16 heads) with incomplete CT images were excluded. Clear images of the superior orbital vessels were collected from all 86 samples, and each sample provided a 3D CT data set acquired from the injection of contrast dye into different arteries. The location, course, and anastomoses of the superior orbital vessels and their relationship with the forehead arteries were recorded.

RESULTS

Overview of the superior orbital arcades

In the current study, the superior orbital vessels consistently deployed 2 distinctive layers: the deep layer and the superficial layer. The former is close to the periosteum, and the latter lies beneath the dermis of the skin in the adipose tissue. The superior orbital

Abbreviations used:

3D:	3-dimensional
CT:	computed tomography
ECA:	external carotid artery
ICA:	internal carotid artery

arcades emerged from the superior part of the medial orbital rim and were divided into the superficial superior orbital arcade and deep superior orbital arcade. The study found that 44.2% (38/86) of the hemifaces had deep superior orbital arcades and that 97.7% (84/86) of the hemifaces had superficial superior orbital arcades, both running laterally along the superior orbital rim to the temporal region and anastomosing with the temporal arteries. In addition, 15.1% (13/86) of the hemifaces had deep superior orbital arteries that branched off the deep branch of the supraorbital artery near the supraorbital foramen (notch) without anastomosing with the temporal arteries (Fig 1). Of the deep superior orbital arcades and deep superior orbital arteries, all were derived from the ophthalmic artery. For the superficial superior orbital arcades, there are 4 different origins: 7.1% (6/84) originated from the superior medial palpebral artery (Fig 1), 3.6% (3/84) originated from the angular artery (Fig 2), 85.7% (72/84) directly originated from the ophthalmic artery (Fig 3), and 3.6% (3/84) originated from the anastomosis between the angular artery and ophthalmic artery (Fig 4). The superficial and deep superior orbital arcades directly anastomosed with the zygomatico-orbital artery (Fig 2), transverse facial artery perforators (Fig 1), and frontal branch of the superficial temporal artery or formed the lateral orbit and malar plexus in conjunction with the temporal arteries.

Relationship between the superior orbital arcades and forehead arteries

The periorbital arteries deployed 2 distinctive layers of the branch arteries to the forehead. The deep branch of the supratrochlear artery and deep branch of the supraorbital artery appeared to run fairly close to the frontal bone, and the superficial branch of the supratrochlear artery and superficial branch of the supraorbital artery lay in a relatively superficial plane. Of the deep layers of the forehead arteries, all deep branches of the supratrochlear artery and deep branches of the supraorbital artery originated from ophthalmic angiosomes. The deep branch of the supratrochlear artery was absent in 46.5% of the hemifaces, but the deep branch of the supraorbital artery was present in 100% of the hemifaces. Deep superior orbital arcades branching off the deep branch of the supratrochlear artery and deep branch of the supraorbital artery were found in 44.2% (38/86) of the hemifaces (Fig 2). Deep superior orbital arteries branching off the deep branch of the supraorbital artery near the supraorbital foramen (or notch) were found in 15.1% (13/86) of the hemifaces. The superficial branch of the supratrochlear artery and superficial branch of the supraorbital artery were present in all cadaver heads. The study found that the superficial superior orbital arcades of 47 hemifaces branched off the superficial branch of the supratrochlear artery and superficial branch of the supraorbital artery (Fig 2); additionally, only the superficial branch of the supraorbital artery originated from the superficial superior orbital arcades in 34 hemifaces, among which the superficial branch of the supratrochlear artery of 12 hemifaces originated from the angular artery, and the superficial branch of the supratrochlear artery of 22 hemifaces directly originated from the ophthalmic artery. For 3 hemifaces, only the superficial branch of the supratrochlear artery originated from the superficial superior orbital arcades, and the superficial branch of the supraorbital artery directly originated from the ophthalmic artery.

DISCUSSION

Previous studies have shown that the upper eyelid vascular system originates from the medial and lateral palpebral arteries. However, some studies have shown that this system is much richer and far more complex than originally believed. The arteries of the upper eyelids anastomose with the ICA system via the ophthalmic artery and with the ECA system via the facial artery and superficial temporal artery.[23-26] Most studies have shown that the upper eyelid contains the marginal arcade and peripheral arcade,[23,24,27,28] but the origins of the arcades near the orbital rim have not been clearly defined and remain controversial.

Injections to sunken eyelids require an experienced physician with comprehensive knowledge of the vascular system because injections in this area are highly likely to lead to ocular complications. The textbook by Cormack and Lamberty[29] notes the presence of branching from the supraorbital artery, which runs horizontally and laterally deep to the eyebrow and anastomoses with the zygomatico-orbital artery to form the periorbital arterial ring. Kawai et al[24] identified superficial and deep orbital arcades by using cadaver dissection and traditional angiography. These arcades were formed by anastomoses of the branches of the zygomatico-orbital artery, transverse facial artery, or frontal branch of the superficial temporal artery laterally and the

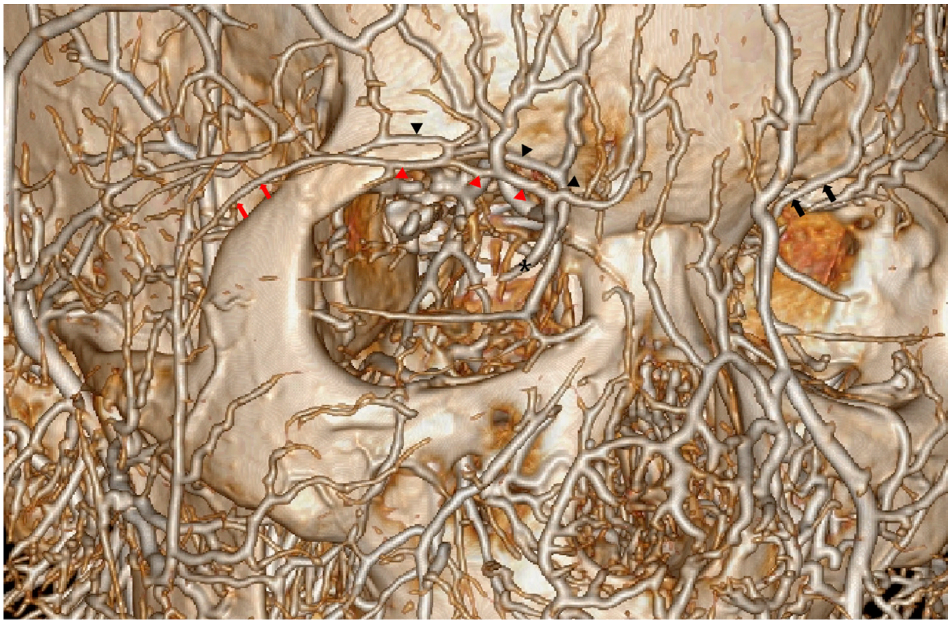

Fig 1. A 3-dimensional computed tomography scan acquired with a Philips device (Philips Healthcare, Cleveland, OH) clearly shows the deep (black arrowheads) and superficial superior orbital arcade (red arrowheads) in the right hemiface and the deep superior orbital artery (black arrows) in the left hemiface. The asterisk indicates the superior medial palpebral artery, and red arrows indicate the transverse facial artery perforators.

branches of the supratrochlear artery, ophthalmic artery, or medial palpebral artery medially. The supratrochlear artery contributed significantly to both the superficial and deep orbital arcades. Lopez et al[27] dissected 5 fresh cadavers and identified an arcade that runs along the orbital septum similar to the preseptal arcade, possibly corresponding to the deep orbital arcade described by Kawai et al,[24] which seems to resemble an anastomosis between the supraorbital and supratrochlear arteries more than the supratrochlear artery itself. In this study, we found that the ophthalmic artery, rather than the supratrochlear artery, contributed significantly to the origins of both the superficial and deep orbital arcades, which means that injections near the orbital rim are highly susceptible to ocular complications. Zhu et al[19] and Zhao et al[21] defined the artery that runs laterally along the superior orbital rim as the superior palpebral artery. Tansatit et al[30] found that the ophthalmic artery divided the superior orbitoglabellar artery running along the orbital rim. In contrast to traditional anatomic studies, this study used high-throughput postmortem 3D CT to visualize arterial arcades near the orbital margin in 86 contrast-infused hemifaces from 51 cadaver heads. We clearly identified the deep and superficial superior orbital arcades running laterally along the superior orbital rim by using high-throughput postmortem 3D CT, which enabled us to separately identify the origins of the deep and superficial orbital superior arcades.

A cannula can be used to correct a sunken upper eyelid by injecting both the preperiosteal plane and the subcutaneous plane. We found that the probability of encountering a patient with superficial superior orbital arcades (84/86) is higher than that of encountering a patient with deep superior orbital arcades (38/86). These findings suggest that the preperiosteal plane may be safer for injections than the subcutaneous plane. Additionally, 13 hemifaces had deep orbital superior arteries that ran laterally along the superior orbital rim and terminated near the supraorbital foramen (notch), indicating that the superior part of the medial orbital rim is more dangerous than the superior part of the lateral orbital rim during filler injections. When the upper eyelids are augmented, fillers should not be injected horizontally into the orbital rim. In contrast, to avoid intravascular injections, fillers should be injected into the orbital rim at an angle, and a slow retrograde injection technique is advised. In 3 hemifaces, the superficial superior orbital arcades originated from the angular artery, which shows that these superficial superior orbital arcades originate from the ECA system and are the anastomosis between the facial angiosomes and superficial temporal angiosomes. In another 3 hemifaces, the superficial superior orbital arcades originated from the anastomosis between

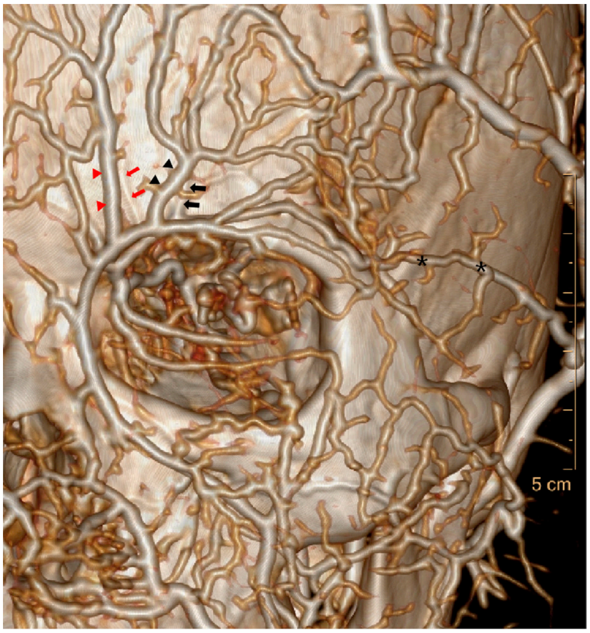

Fig 2. A 3-dimensional computed tomography scan showing that the deep branch of the supratrochlear artery (red arrows) and deep branch of the supraorbital artery (black arrows) jointly originate from the deep superior orbital arcades and that the superficial branch of the supratrochlear artery (red arrowheads) and superficial branch of the supraorbital artery (black arrowheads) jointly originate from the superficial superior orbital arcade. The asterisks indicate the zygomatico-orbital artery.

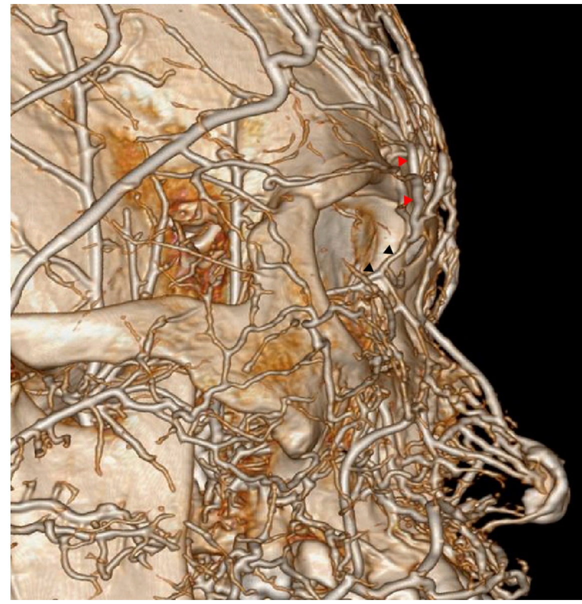

Fig 3. A 3-dimensional computed tomography scan showing that the superficial superior orbital arcade (red arrowheads) originates from the ophthalmic artery (black arrowheads).

Fig 4. A 3-dimensional computed tomography scan showing that the superficial superior orbital arcade (red arrowheads) originates from the anastomosis between the angular artery (red arrows) and ophthalmic artery (black arrows).

the angular artery and ophthalmic artery, which shows that these superficial superior orbital arcades originated from the ECA and ICA systems.

The forehead is one of the most common areas for soft tissue filler injections and is of great esthetic significance because it is easily visible near the eyes and often shows signs of early aging. Soft-tissue filler injections into the superficial and periosteal positions have been used to restore frontal volume.[31] The supratrochlear artery and supraorbital artery that branch from the ophthalmic artery provide a rich blood supply for the forehead, making the forehead a high-risk injection site for vascular complications.[32] To minimize risks, many studies have been conducted to detail the forehead vasculature, especially the branching and distribution patterns of the supratrochlear artery and the supraorbital artery, thereby providing clinical guidelines for forehead filler injections. Erdogmus and Govsa[33] found that there is an 87% chance that the supraorbital artery and the supratrochlear artery arise from the orbit as 2 separate vessels. Tansatit et al[30] believed that the forehead arteries depended on the superior orbitoglabellar artery, which ascends along the supraorbital rim and branches off the supratrochlear artery and the supraorbital artery. Cong et al[32] classified the distributions of the supratrochlear and supraorbital arteries by their relationship to the frontalis. By using high-throughput postmortem 3D CT, we found that the orbital arcades have a complex relationship with the supratrochlear artery and supraorbital artery. For deep forehead arteries, the deep branch of the supratrochlear artery was absent in 46.5% of the hemifaces, with the deep branch of

Fig 5. A 3-dimensional computed tomography scan showing that the superficial branch of the supratrochlear artery (red arrows) originates from the facial artery (black arrows) through the angular artery.

the supraorbital artery observed in 100% of the hemifaces, which is consistent with Cong et al's study. Thirty-eight (44.2%) hemifaces had deep orbital arcades, which bifurcated into the deep branch of the supratrochlear artery and deep branch of the supraorbital artery, possibly corresponding to the orbitoglabellar artery branching off the supratrochlear artery and the supraorbital artery; this means that the supratrochlear artery and supraorbital artery do not directly originate from the ophthalmic artery. The deep branch of the supratrochlear artery and deep branch of the supraorbital artery arose from the orbital rim as 2 separate vessels in 6 hemifaces.

When the deep branch of the supratrochlear artery was absent, the deep branch of the supraorbital artery emerged from the supraorbital foramen (or notch) at the lower margin of the orbital rim or originated from the deep orbital arteries near the supraorbital foramen (or notch) and ran close to the frontal bone. The superficial arteries are more complex than the deep arteries. Importantly, the superficial orbital arcades contributed significantly to the origins of the superficial branch of the supratrochlear artery and superficial branch of the supraorbital artery. The angular artery has been applied in pedicled flap designs and reconstructive surgeries to treat skin cancer, fistulae, and facial injuries. In addition, the angular artery is closely associated with fatal complications, such as skin necrosis and vision loss.[34-36] This study found that the angular arteries of 3 hemifaces ran vertically to the nasojugal and medial canthal areas and bifurcated into the superficial branch of the supratrochlear artery and superficial branch of the supraorbital artery, which means that injections to the nasolabial fold may cause skin necrosis of the upper eyelid and forehead. Additionally, in 12 hemifaces, the superficial branch of the supratrochlear artery originated from the facial artery through the angular artery (Fig 5), which means that injections to the nasolabial fold may cause skin necrosis of the central forehead.

CONCLUSION

Because of a variation of blood vessel connections and anastomoses, it is important to be familiar with all facial vasculature to minimizing adverse events during filler injections. A comprehensive understanding of the 3-dimensional vascular anatomic features of the eyelid is essential for injections to correct sunken eyelids. Postmortem 3D CT provided a thorough examination of the superior orbital vessels and their relationship with the forehead arteries, elucidating novel arterial systems of the periorbital region and helping minimize the risks associated with filler injections.

REFERENCES

1. Rohrich RJ, Coberly DM, Fagien S, et al. Current concepts in aesthetic upper blepharoplasty. *Plast Reconstr Surg*. 2004; 113(3):32e-42e.
2. Fagien S. Advanced rejuvenative upper blepharoplasty: enhancing aesthetics of the upper periorbita. *Plast Reconstr Surg*. 2002;110(1):278-291.
3. Liew S, Nguyen DQ. Nonsurgical volumetric upper periorbital rejuvenation: a plastic surgeon's perspective. *Aesthetic Plast Surg*. 2011;35(3):319-325.
4. Weng CJ, Noordhoff MS. Complications of oriental blepharoplasty. *Plast Reconstr Surg*. 1989;83(4):622-628.
5. Ciuci PM, Obagi S. Rejuvenation of the periorbital complex with autologous fat transfer: current therapy. *J Oral Maxillofac Surg*. 2008;66(8):1686-1693.
6. Tonnard PL, Verpaele AM, Zeltzer AA. Augmentation blepharoplasty: a review of 500 consecutive patients. *Aesthet Surg J*. 2013;33(3):341-352.
7. Tung TC, Tsai TR, Yu CC, et al. Simultaneous fat removal with suture upper blepharoplasty. *Aesthetic Plast Surg*. 2012;36(4): 842-845.
8. Chen HH, Williams EF. Lipotransfer in the upper third of the face. *Curr Opin Otolaryngol Head Neck Surg*. 2011;19(4):289-294.

9. Romeo F. Upper eyelid filling with or without surgical treatment. *Aesthetic Plast Surg*. 2016;40(2):223-235.
10. Lin TM, Lin TY, Huang YH, et al. Fat grafting for recontouring sunken upper eyelids with multiple folds in Asians—novel mechanism for neoformation of double eyelid crease. *Ann Plast Surg*. 2016;76(4):371-375.
11. Lee W, Kwon SB, Oh SK, et al. Correction of sunken upper eyelid with orbital fat transposition flap and dermofat graft. *J Plast Reconstr Aesthet Surg*. 2017;70(12):1768-1775.
12. Lee Y, Kwon S, Hwang K. Correction of sunken and/or multiply folded upper eyelid by fascia-fat graft. *Plast Reconstr Surg*. 2001;107(1):15-19.
13. Beleznay K, Carruthers JD, Humphrey S, et al. Avoiding and treating blindness from fillers: a review of the world literature. *Dermatol Surg*. 2015;41(10):1097-1117.
14. Talbot SG, Parrett BM, Yaremchuk MJ. Sepsis after autologous fat grafting. *Plast Reconstr Surg*. 2010;126(4):162e-164e.
15. Li XQ, Wang TL, Wang JQ. Ptosis: an underestimated complication after autologous fat injection into the upper eyelid. *Aesthet Surg J*. 2015;35(6):Np147-Np153.
16. Tang M, Yin Z, Morris SF. A pilot study on three-dimensional visualization of perforator flaps by using angiography in cadavers. *Plast Reconstr Surg*. 2008;122(2):429-437.
17. Mundada P, Kohler R, Boudabbous S, et al. Injectable facial fillers: imaging features, complications, and diagnostic pitfalls at MRI and PET CT. *Insights Imaging*. 2017;8(6):557-572.
18. Tang M, Ding M, Almutairi K, et al. Three-dimensional angiography of the submental artery perforator flap. *J Plast Reconstr Aesthet Surg*. 2011;64(5):608-613.
19. Zhu GZ, Zhao WR, Luo CE, et al. High-throughput screening of full-face clinically relevant arterial variations using three-dimensional postmortem computed tomography. *Plast Reconstr Surg*. 2018;142(5):653e-664e.
20. Wong C, Nagarkar P, Teotia S, et al. The profunda artery perforator flap: investigating the perforasome using three-dimensional computed tomographic angiography. *Plast Reconstr Surg*. 2015;136(5):915-919.
21. Zhao WR, Wang HB, Luo CE, et al. Three-dimensional computed tomographic study on the periorbital branches of the ophthalmic artery: arterial variations and clinical relevance. *Aesthet Surg J*. 2019;39(10):1109-1117.
22. Ozek C, Zhang F, Lineaweaver WC, et al. New simplified radio-opaque injection technique for visualization of rat arteries. *Microsurgery*. 1996;17(6):321-323.
23. Gausas RE. Advances in applied anatomy of the eyelid and orbit. *Curr Opin Ophthalmol*. 2004;15(5):422-425.
24. Kawai K, Imanishi N, Nakajima H, et al. Arterial anatomical features of the upper palpebra. *Plast Reconstr Surg*. 2004;113(2):479-484.
25. Tezel E, Sönmez A, Numanoğlu A. Medial pedicled orbicularis oculi flap. *Ann Plast Surg*. 2002;49(6):599-603.
26. Tucker SM, Linberg JV. Vascular anatomy of the eyelids. *Ophthalmology*. 1994;101(6):1118-1121.
27. Lopez R, Lauwers F, Paoli JR, et al. The vascular system of the upper eyelid. Anatomical study and clinical interest. *Surg Radiol Anat*. 2008;30(3):265-269.
28. Edizer M, Beden U, Icten N. Morphological parameters of the periorbital arterial arcades and potential clinical significance based on anatomical identification. *J Craniofac Surg*. 2009;20(1):209-214.
29. Cormack G, Lamberty B. *The Arterial Anatomy of Skin Flaps*. London, UK: Churchill Livingstone; 1994.
30. Tansatit T, Phumyoo T, Jitaree B, et al. Anatomical and ultrasound-based injections for sunken upper eyelid correction. *J Cosmet Dermatol*. 2020;19(2):346-352.
31. Sykes JM. Applied anatomy of the temporal region and forehead for injectable fillers. *J Drugs Dermatol*. 2009;8(10 Suppl):s24-s27.
32. Cong LY, Phothong W, Lee SH, et al. Topographic analysis of the supratrochlear artery and the supraorbital artery: implication for improving the safety of forehead augmentation. *Plast Reconstr Surg*. 2017;139(3):620e-627e.
33. Erdogmus S, Govsa F. Anatomy of the supraorbital region and the evaluation of it for the reconstruction of facial defects. *J Craniofac Surg*. 2007;18(1):104-112.
34. Brunetti B, Tenna S, Aveta A, et al. Angular artery perforator flap for reconstruction of nasal sidewall and medial canthal defects. *Plast Reconstr Surg*. 2012;130(4):627e-628e.
35. Kim SW, Kim YH, Kim JT. Angular artery perforator-based transposition flap for the reconstruction of midface defect. *Int J Dermatol*. 2012;51(11):1366-1370.
36. Huang YH, Lai CS, Lin SD, et al. Angular artery cutaneous flap for reconstruction of difficult oronasal fistulas. *Ann Plast Surg*. 2011;67(6):597-599.