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Arterial Anatomy of the Tear Trough Region in Chinese Cadavers: Implications for Injection Safety

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Abstract
Background The safety of tear trough injections requires examination of the arterial topography in this region.
Objectives The aim of this study was to elucidate the distribution of blood vessels in the tear trough region at a specific three-dimensional (3D) location.
Methods Computed tomography scans of 158 adult cadaver hemifaces were obtained and reconstructed, focusing on the origin of angular artery (AA) and the positioning of detoured facial artery (DeFA).
Results The AA in the tear trough region has three main sources: 57.6% directly from the ophthalmic artery (OA), 38% from branches of the facial artery (FA), and 4.4% from branches of the infraorbital artery (IOA). Within this region, the detoured AA originating from the OA is observed in 3.8% of cases, located at a mean distance of 3.4 ±2.0 mm from the inferior orbital margin near the inner canthus. The DeFA is present in 38.6% of cases, located at a mean distance of 7.3 ±2.8 mm from the inferior orbital margin near the inner canthus. Additionally, the main arterial supply to the infraorbital area is provided by branches of the IOA (53.8%).
Conclusions 3D technology enables offer high-resolution guidance for clinical practice in the tear trough area.

Level of Evidence IV This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keyword Tear trough injection · Infraorbital artery · Angular artery · Detoured facial artery

Introduction

Minimally invasive procedures that utilize filler injections have proven to be effective and popular for maintaining a youthful appearance [1]. As facial muscles and tissues deteriorate with age, concerns about these signs of aging are increased [2]. This is particularly evident in cases of tear trough deformities. The tear trough is the nasojugal groove, located inner side of the eye, the groove undermines the fullness and appearance of the infraorbital region, often imparting a pale and gaunt appearance [3]. Although generally safe, the filler injection can lead to complications such as bruising, skin necrosis, and impaired vision, which are primarily linked to vascular damage [4, 5].

The administration of soft tissue fillers in the tear trough region poses challenges due to its high vascularity, which intersects with numerous branches of the ocular and facial vascular systems [6, 7]. The angular artery (AA) and angular vein (AV) are positioned superficially near the tear trough [8]. These are terminal branches connecting facial to ocular vessels, and damage to these vessels can lead to significant visual impairment [5]. Jitaree and co-workers identified the AA as the artery branch nearest to the tear trough, typically approaching the surface of the orbicularis

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oculi muscle at approximately 4.0 mm from the infraorbital rim [7]. Cotofana and co-workers noted that the AV traverses the supraosseous plain of the tear trough at an average distance of 4.2 mm from the infraorbital rim [9]. Furthermore, the detoured facial artery (DeFA) and the infraorbital artery (IOA) also contribute branches that serve the tear trough region, thereby heightening the risk of vascular injury from filler injections [6, 10]. Identifying the precise locations of these arteries and their connections is essential to mitigate vascular complications.

Previous studies have detected clinical arterial variants in the face using traditional cadaveric dissection and three-dimensional (3D) computed tomography (CT) scans [6, 7]. However, the relationship between the ophthalmic artery and the facial artery for tear trough injection remains unclear, and the locations of the detoured AA and FA detected in the tear trough region have not been extensively explored. Therefore, this study employs 3D CT scanning to analyze the arteries in the face, aiming to provide comprehensive details on the vasculature in the tear trough area to reduce the potential for serious complications following filler injections.

Materials and Methods

Study Sample

Between June 2023 and June 2024, this study was undertaken in accordance with the principles set forth in the Declaration of Helsinki. Eighty-four fresh frozen cadaveric heads of Han Chinese descent were procured from the voluntary cadaver donation program, adhering to the ethics guidelines established by the Chinese Ministry of Health for autopsy procedures.

Preparation of Cadaver and CT Evaluation

CT imaging procedures were conducted following previously documented protocols [11]. Each facial artery received an injection of a mixture containing lead oxide (Guang Hua Chemical Company, Shan Tou City, China), along with 5 mL of red dye and 100 mL of latex. Subsequently, cadaveric head CT scans were performed using a 64-row spiral CT scanner (Philips Brilliance 64; Philips, Cleveland, OH). The scanning parameters included a tube voltage of 120 kV, an effective tube current of 250 mA, a data acquisition trigger of 140 HU, a field of view measuring 500 × 600 mm, and a slice size above baseline of 1024 × 1024 pixels. Each slice had a thickness of 0.8 mm, with an interslice increment of 0.4 mm. A Philips IntelliSpace workstation, configured with default settings, was employed to transform the 2D CT image volume of each specimen into a 3D CT image.

The scope of the study is as follows:

Multiple points were chosen for spatial measurements to determine the precise location and extent of the artery. A horizontal reference line was established as a straight line extending from the upper edge of the tragus to the lower edge of the orbit, aligning with the Frankfort horizontal line [12]. The orbital width was divided into four equal segments. The positions and extents of both the AA and DeFA were examined and documented using vertical reference lines L0 to L4, which run parallel to the midsagittal line (Figure 1).

All bilateral measurements were performed with Mimics software (Materialise version 19.0). The following parameters were evaluated (in mm):

- The horizontal distance from the vertical line at the medial canthus to reference line L1.
- Vertical distances from the arteries located at vertical reference lines L1 and L2 to the inferior orbital rim (VL1–VL2).
- Vertical and horizontal measurements from the detoured facial artery to the corners of the mouth and the lower edge of the nose.
- Several distinct arteries were noted along vertical reference lines L1 to L4, positioned within 5 mm of the inferior orbital rim.

Results

The heads of 84 cadavers (168 half-faces) were studied with 3D CT scans. Incomplete data from 10 half-faces were excluded resulting in 158 half-face 3D images involving 43 males and 36 females. The age of the cadavers ranged from 21 to 65 years old. Measurements included a periorbital

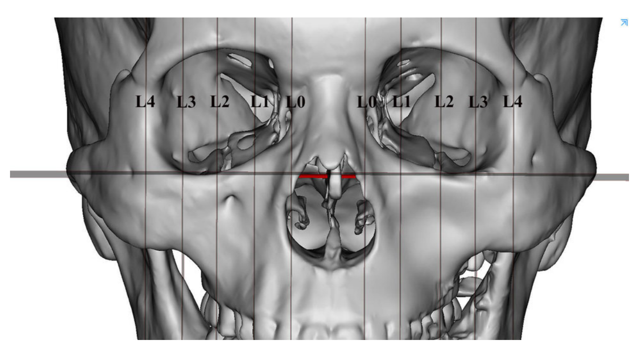

Fig. 1 The horizontal reference line was defined as a straight line extending from the upper edge of the tragus to the lower orbital rim, following the Frankfort horizontal line. The orbital width was divided into four equal segments, and the vertical reference line was established as L0 to L4, parallel to the midsagittal line.

length of 41.4 ±2.3 mm (range 35.7–46.8 mm) and a periorbital height of 35.3 ±2.1 mm (range 30.0–40.2 mm). The horizontal distance from the medial canthus to vertical line L1 averaged –1.0 ±1.4 mm (range: –2.2 to 5.1 mm).

Overview of AA

The AA acts as a connection between the facial and ophthalmic vessels. In the tear trough area, three origins of the AA were identified: 57.6% (91/158) directly from the ophthalmic artery (OA), 38.0% (60/158) from branches of the facial artery (FA), and 4.4% (7/158) from branches of the IOA (Figure 2).

In most cases, the AA originating from the ophthalmic artery follows a route along the medial edge of the orbital bone and the nasojugal groove, consistently ending near the nose. In a minority of cases, this AA from the ophthalmic artery displayed abnormal detoured branches (DeAA) that diagonally traversed the infraorbital region (Figure 3). The incidence of DeAA originating from the OA was 3.8% (6/158), with distances from the infraorbital rim on L1 and L2 measuring VL1 = 3.4 ±2.0 mm (range: 1.3–5.7 mm) and VL2 = 8.5 ±3.2 mm (range: 5.8–12.0 mm), respectively.

Anastomotic branches between the AA originating from the ophthalmic artery and the IOA occurred in 8.2% (13/158) of cases (Table 1). The distances of these anastomotic branches from the inferior orbital rim on L1 and L2 were VL1 = 5.8 ±3.7 mm (range: 0–12.4 mm) and VL2 = 10.8 ±3.4 mm (range: 3.2–17.3 mm), respectively.

Location of the Detoured Facial Artery

The FA gives rise to a convoluted trunk near the corner of the mouth and the nasolabial artery trunk, running along the anterior border of the masseter muscle (i.e., DeFA). The results indicated DeFA in 38.6% (61/158) of hemifaces, with 62.3% (38/61) of these cases showing DeFA continuation at the medial canthus as the AA connecting with the OA branch. Additionally, symmetrical DeFAs were observed in 22.8% of cadaveric heads, with occurrences in 26 right and 35 left hemifaces. The distances from the inferior orbital rim on L1 and L2 were 7.3 ±2.8 mm (range: 1.0–13.2 mm) for VL1 and 12.7 ±5.1 mm (range: 4.6–31.0 mm) for VL2.

Two types of DeFAs were identified based on their origin locations (Table 2 and Figure 4). Type I DeFA, originating near the corners of the mouth, was present in 78.7% (48/61) of cases. This type of DeFA extended upward and medially supplying arterial flow to the muscles of the mid-face and the superficial subcutaneous area. Type II DeFA, a slender branch of the FA originating near the nasal flanks, accounted for 21.3% (13/61) of cases. Additionally, DeFA branches form precise anastomoses with OA branches and extensive anastomoses with IOA branches.

Distribution of Identifiable Arteries Within 5 mm of the Inferior Orbital Rim

The arterial structure of the infraorbital region is highly intricate (Figure 5). Studies have identified that the medial area is supplied by vascular networks from the FA, OA, and IOA, while the lateral area is supplied by the FA, IOA, posterior superior alveolar artery (PSAA), zygomatic-orbital artery (ZOA), zygomaticofacial artery (ZFA), and transverse facial artery (TFA). Notably, branches of the IOA (53.8%) primarily supply the infraorbital region. Among these, the nasal (L1), palpebral (L2), and orbital (L3) branches of the IOA are particularly vulnerable in this region.

Discussion

The tear trough, located in the midface, is a common area for filler injections and serves as a significant indicator of aging in the periorbital region [13]. The depression line of the tear trough runs from the medial canthus to the inferior lateral aspect, parallel to the infraorbital rim [14]. The vascular supply to this area involves a complex arterial system, with branches such as the OA, FA, and IOA contributing to its circulation [6, 7]. However, the intricate

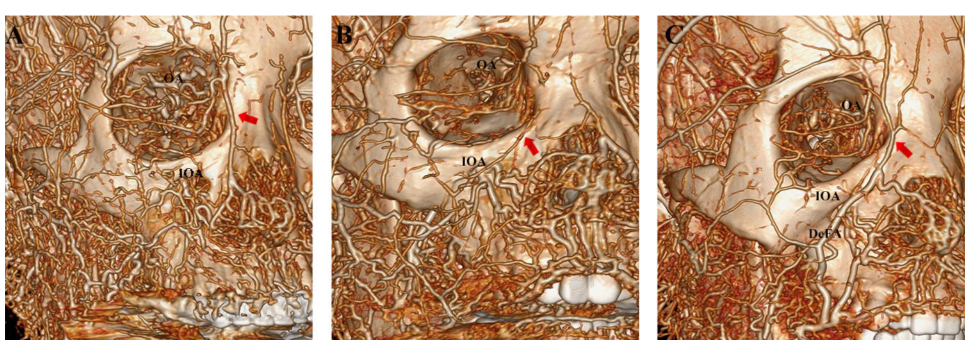

Fig. 2 Sources of the angular artery (AA): **A** Origin from the ophthalmic artery (OA); **B** Origin from the infraorbital artery (IOA); **C** Origin from the detoured facial artery (DeFA). The red arrow indicates the AA.

Fig. 3 The detoured angular artery (DeAA). FA, facial artery; IOA, infraorbital artery; OA, ophthalmic artery; AA, angular artery. The red arrow indicates the DeAA.

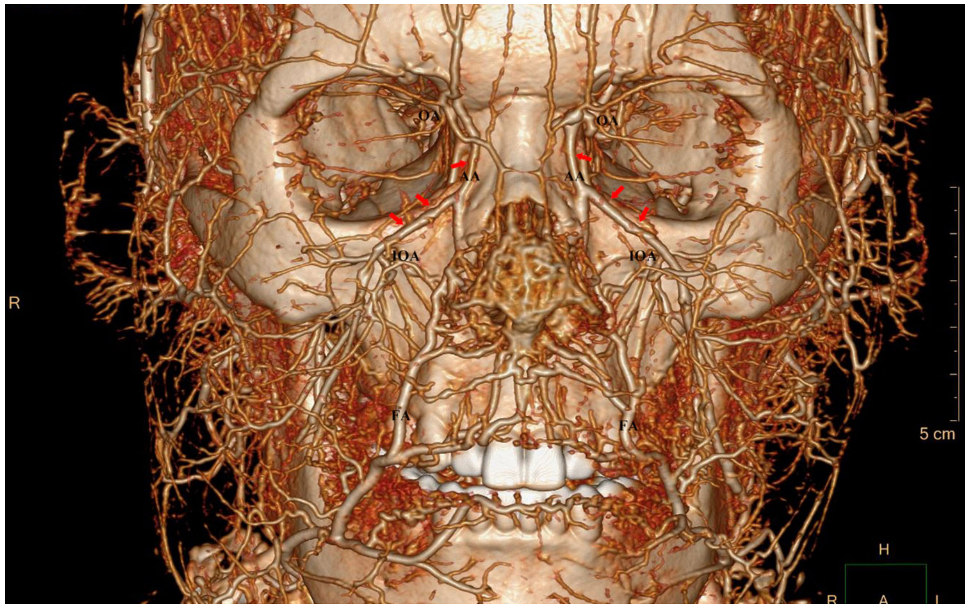

Table 1 Location of vulnerable angular artery (AA) branches

Reference points for measurement of distance	AA of OA origin		AA of IOA origin		AA and IOA anastomotic vascular branches	
	Distance (mm)	Diameter(mm)	Distance (mm)	Diameter(mm)	Distance (mm)	Diameter(mm)
VL1	3.4±2.0	2.3±0.3	6.9±3.8	1.0±0.1	5.8±3.7	1.3±0.4
VL2	8.5±3.2	1.3±0.3	8.4±3.3	1.3±0.3	10.8±3.4	1.2±0.3

OA ophthalmic artery; *AA* angular artery; *IOA* infraorbital artery; *VL1* Vertical distance from the lower margin of the orbital bone on L1; *VL2* Vertical distance from the lower margin of the orbital bone on L2

Table 2 Location of the detoured facial artery (DeFA)

Reference points for measurement of distance	TypeI DeFA		TypeII DeFA	
	Distance(mm)	Diameter(mm)	Distance(mm)	Diameter(mm)
VL1	7.1±2.8	1.8±0.5	8.0±2.9	1.6±0.6
VL2	11.7±3.4	2.1±0.6	16.7±8.3	1.9±0.8
VM	5.4±3.1	2.3±0.5		
HM	9.3±3.3			
VN			− 1.7±4.2	2.0±0.6
HN			8.1±3.0	

DeFA detoured facial artery; *VL1* Vertical distance from the lower margin of the orbital bone on L1; *VL2* Vertical distance from the lower margin of the orbital bone on L2; *VM* vertical distance from the corner of the mouth; *HM* horizontal distance from the corner of the mouth; *VN* vertical distance from the nasal flange; *HN* horizontal distance from the nasal flange

vascular anatomy of the tear trough region increases the vulnerability of vessels to injury during injection procedures leading to complications such as bruising and potentially serious issues like vascular filler embolization [4, 5]. Consequently, treating tear trough deformities requires a high level of technical skill and precision compared to other facial regions.

The tear trough area, traversed by the AA, is acknowledged as particularly vulnerable to the risk of blindness [7, 8]. Serkies-Minuth and co-workers documented a case

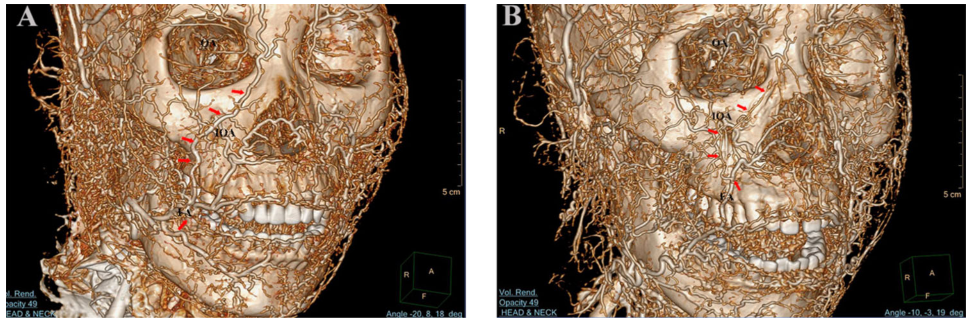

Fig. 4 Classification of the detoured facial artery (DeFA): **A** Type I DeFA; **B** Type II DeFA. FA, facial artery; IOA, infraorbital artery; OA, ophthalmic artery. The red arrow indicates the DeFA.

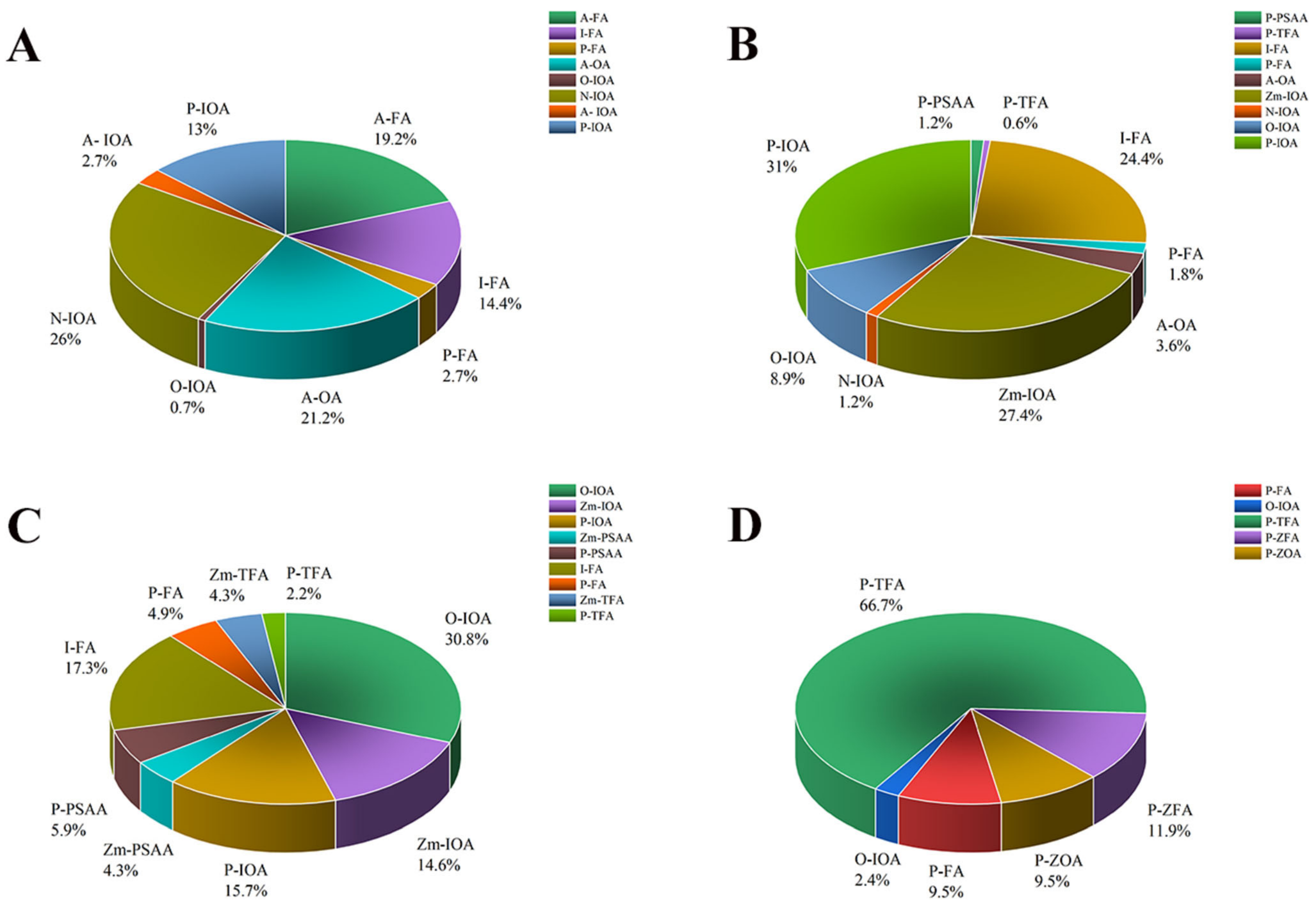

Fig. 5 Distribution of identifiable arteries within 5 mm of the inferior orbital rim: **A** L1; **B** L2; **C** L3; **D** L4. P-FA, palpebral branch of facial artery; A-FA, angular branch of facial artery; I-FA, infraorbital branch of facial artery; O-IOA, orbital branch of infraorbital artery; P-IOA, palpebral branch of infraorbital artery; N-IOA, nasal branch of infraorbital artery; Zm-IOA, zygomatico-malar branch of infraorbital artery; A- IOA, angular branch of infraorbital artery; A-OA, angular branch of ophthalmic artery; P-TFA, palpebral branch of transverse facial artery; Zm-TFA, zygomatico-malar branch of transverse facial artery; P-PSAA, palpebral branch of posterior superior alveolar artery; Zm-PSAA, zygomatico-malar branch of posterior superior alveolar artery; P-ZFA, palpebral branch of zygomaticofacial artery; P-ZOA, palpebral branch of zygomatico-orbital artery.

of Purtscher-like retinopathy resulting from cosmetic filler injection to enhance the tear trough [5]. Nonetheless, there is scant research investigating the anatomical reasons behind complications arising from cosmetic filler injections in this specific area.

The arterial supply around the tear trough deformity is closely linked to the vascular distribution in the infraorbital region. Typically, branches of the AA and IOA supply blood to the medial segment of the infraorbital region [7]. Recently, Shin and co-workers reported that the AA is frequently found between the middle of the medial canthus and the midline of the face, approximately 9 mm from the medial canthus [15]. Kelly and co-workers demonstrated that the AA predominantly supplies blood to the paranasal region, terminating in the nasal flanks [16]. Using ultrasonography to study lacrimal trough anatomy, Calomeni and co-workers found the AA consistently traveling vertically parallel to the medial AV in all cases examined [8]. Other anatomical studies indicate that the AA is not always the terminal branch of the FA and can originate from the IOA or the OA [7, 17]. Toure and co-workers noted that the robust TFA may substitute for the underdeveloped FA, extending into the AA and anastomosing with the dorsal nasal artery, which can lead to blindness following lateral injections [18]. Moreover, the AA primarily anastomoses with the OA regardless of its origin potentially connecting branches of the angular region arteries to intracranial vessels [19].

However, our study yielded different findings. In some special cases, a few AAs emit branches diagonally in the infraorbital region (Figure 3). This particular trunk is often overlooked when these arteries take an abnormal course. However, its consideration is crucial during filler injections in the tear trough region due to the risk of direct arterial injury or extravascular compression potentially causing clinical complications such as bruising, skin necrosis, and even blindness given the direct connection to the OA [4, 5]. A more precise characterization of the detoured AA (DeAA) is necessary to ensure the safety of injection treatments. Additionally, in some instances, the AA originating from the ophthalmic artery anastomoses with the branches of the IOA (8.2%). The smaller branches of the OA play a critical role in supplying the medial canthal tissues. This anastomosis provides a retrograde pathway for filler material potentially leading to embolic dispersion into the central retinal artery and subsequent vision loss [5].

The FA supplies blood to facial muscles and superficial subcutaneous layers typically with its terminal branches ascending along the lateral aspect of the nose [20]. However, in 2–30% of cases, an additional distinct branch from the FA near the corner of the mouth, known as DeFA, has been observed [21–24]. The terminal segment of DeFA provides blood supply to the inner canthus region [23]. Kim and co-workers reported that 19% of FAs continue directly into the AA, while 32% of DeFAs continue into the AA [17]. Moreover, the AA originating from the facial artery often overlaps with branches of the ophthalmic artery. Through 3D computed tomography, we identified tortuous FA anatomy in up to 38.6% of the hemifacial region. Among these, 78.7% of DeFAs originated 9.3 mm lateral and 5.4 mm superior to the corners of the mouth extending upward and medially to the medial orbital rim and connecting with OA branches and distributing throughout the infraorbital region away from the nose. Our findings corroborate those of Cong and co-workers [10]. However, our study incorporates the location of the orbital bones to precisely describe the distance of DeFA from the infraorbital bone, ensuring safer tear through injection procedures.

Interestingly, we evaluated the position of the medial canthus in the orbital width and found it to be 1.0 ±1.4 mm (range –2.2 to 5.1 mm) medial to one-quarter of the orbital width. Thus, the medial canthus serves as a reliable topographical landmark for identifying the presence of DeAA and DeFA. These arteries pose potential risks during procedures due to the possibility of injection into or compression of these vessels, which can result in adverse postoperative complications [4, 5]. Therefore, understanding the trajectories of DeAA and DeFA is crucial for clinicians performing nonsurgical preoperative assessments to mitigate severe arterial complications when administering filler injections into the tear trough. Importantly, the DeAA is most vulnerable near the medial canthus. We observed that the DeAA was closer to the infraorbital rim (3.4 mm) than the DeFA (7.3 mm).

Gombolevskiy and co-workers recently conducted a study using 156 healthy facial enhancement CT scans, confirming that the AA in Caucasian patients was observed on the surface of the orbicularis oculi muscle in 82.7% of cases, with an average depth of 1.02 mm at the medial canthus [25]. The DeFA is situated on the surface of the orbicularis oculi muscle around the orbital region, suggesting that injecting filler beneath this muscle layer is safer. The intramuscular pathway of the AV within the tear trough further supports a deeper injection strategy to avoid superficial veins and arteries within the orbicularis oculi than previously anticipated. Given the presence of AV and AA, more researchers are advocating for preperiosteal injections to enhance the tear trough region [7, 26].

Previous research has emphasized the significant role of the IOA in the infraorbital region in cases of FA dysplasia [6, 27, 28]. In a cadaveric study by Jitaree and co-workers, it was demonstrated that the nearest artery associated with the tear trough is the palpebral branch of the IOA (PIOA) [7]. Hwang's findings further supported this, confirming the PIOA is located within 40%–80% of the eye's width [29]. Our study additionally identified the nasal (L1), palpebral (L2), and orbital (L3) branches of the IOA as particularly vulnerable vessels in the infraorbital region. Therefore, precise filler injection techniques in the tear trough area of the infraorbital region should meticulously avoid these arteries.

Near the medial canthus, the area traversed by the nasal branch of the IOA above the periosteum is typically considered risky for preperiosteal injections. Therefore, for filler injections in the tear trough area, we recommend positioning injections away from the vertical line of the medial canthus and that injecting suborbicularis and massaging the filler into the medial tear trough was the safest way. Our previous research indicated that the fewest number of vessels were found within 5 mm from the inferior orbital rim [11]. This understanding is crucial for reducing the risk of vascular complications associated with procedural interventions aimed at correcting infraorbital deformities. Furthermore, given the thin and translucent skin in the orbital region, retrograde injections should be minimized, and aspiration should precede injection to mitigate potential risks.

The extensive anastomosis among facial arteries means there is almost no completely safe area or route for injectable fillers. The findings of this study will aid surgeons in navigating vascular complications linked to tear trough injections. However, the limitations of this study are that the samples were from Chinese subject and the CT scans could only detect vessels larger than 0.4 mm in diameter. Therefore, additional investigation is warranted to include greater ethnic diversity among study subjects and further explore the impact of facial veins and the relationship of blood vessels to surrounding structures (fat pads) on the safety of the injections.

Conclusion

This study utilized 3D CT scans to analyze the arterial distribution focusing on the origin of the AA and the positioning of the DeFA. Moreover, we confirmed that the branches of the IOA predominantly supply the infraorbital area. The study highlighted that the medial tear trough is associated with an increased risk of intravascular filler injection. Therefore, we recommend positioning injections away from the vertical line of the medial canthus. Additionally, injecting into the loose areolar plane just below the orbicularis oculi muscle at the level of the medial inferior orbital rim and massaging filler into the medial tear trough is an approach likely to avoid many of the vessels traversing this area.

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Declarations

Conflicts of interest The authors declare there is no conflict of interest.

Ethical Approval The study protocol was approved by the Institutional Review Board of the Guangdong Second Provincial General Hospital.

Informed Consent For this type of study informed consent is not required.

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