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Macroanatomical and Morphometric Investigation on the Maxillary Vein in Rabbits

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Abstract: Fifteen New Zealand rabbits were used in this study. Buffered saline solution was given through the common carotid artery to remove the blood from the cranial veins. The jugular vein was ligated prior to giving blue latex to 10 rabbits and blue Batson's No. 17 to 5 rabbits through the maxillary vein. Rabbits were left for 24 hours in order to let the latex harden and then they were transferred to 10% formaldehyde solution and dissected. Rabbits that were injected with Batson's No17 were kept in 33% KOH solution for 48 hours and corrosion casts were prepared. The diameters of the veins were measured with a digital dial caliper.

It was observed that the pterygoid plexus, the superficial temporal vein, the ascending pharyngeal vein, the caudal auricular vein and the ventral masseteric vein provided 25%, 21%, 21%, 20% and the 13% of the venous blood of the maxillary vein, respectively. Results of estimations of the diameter and the thickness of the vessels showed that the caudal auricular vein was 35% thicker than the rostral auricular vein. In addition, 32%, 23% and 45% of the venous blood coming to the caudal auricular vein was provided by the lateral auricular vein, the intermediate auricular vein and the deep auricular vein, respectively. It was determined that the transverse facial vein provided 40% drainage to the masseteric muscle. Other vessels that drained this muscle were the ventral masseteric vein (41%) continuing caudoventrally and the masseteric vein (19%) going caudodorsally. It was also found that a thin vein provided the drainage of a small caudal part of the nasal cavity, namely the sphenopalatine vein. It was observed that the branches from the palatine plexus passed through the palatine fissure and connected with the nasal venous plexus. Some branches passed on the rostral side through the caudal part of the incisive teeth and went to the apex nasi connected with the superior labial vein. It was determined that the palatine veins originating from the palatine plexus passed through the medial part of the lamina perpendicularis of the palatine bone and connected to the descending palatine vein. The venous plexus of the dorsal nasal concha and the venous plexus of the ventral nasal concha on either side of the cavum nasi were connected at the apex nasi and the caudal part of the cartilago septi nasi respectively. Furthermore, the venous plexus of the ventral nasal concha formed a strong anastomosis with the descending palatine vein at the choana.

Key Words: Maxillary vein, rabbit, morphometry, anatomy.

Tavşanlarda Vena Maxillaris'in Makroanatomik ve Morfometrik Olarak İncelenmesi

Özet: Bu çalışmada 15 adet Yeni Zelanda tavşanı kullanıldı. V. maxillaris'ten 10 adet tavşana mavi renklendirilmiş latex, 5 adet tavşana da mavi renklendirilmiş Batson's No 17 enjekte edildi. Latex verilen tavşanların disseksiyonları yapıldı. Batson's No 17 verilen tavşanlardan da corrosion preparatlar hazırlandı. Venaların çapları dijital bir kumpasla ölçüldü.

Çalışma sonucunda v. maxillaris'in taşıdığı venöz kana plexus pterygoideus'un %25, v. temporalis superficialis'in %21, v. pharyngea ascendens'in %21, v. auricularis caudalis'in %20 ve v. masseterica ventralis'in ise %13 oranında katkı sağladığı belirlendi. Auricula'nın venöz drenajını yapan venalardan v.auricularis caudalis'in v. auricularis rostralis'e göre %35 oranında daha kalın olduğu bulundu. V. auricularis caudalis'e gelen venöz kanın %32'sinin v. auricularis lateralis, % 23'ünün v. auricularis intermedia, %45'inin ise v. auricularis profunda tarafından sağlandığı saptandı. M.masseter'in % 41'inin v. masseterica ventralis, % 40'ının v. transversa faciei ve % 19'unun da v. masseterica tarafından drene edildiği belirlendi. İnce bir vena olan v. sphenopalatina'nın cavum nasi'nin caudal küçük bir kısmını drene ettiği gözlendi. Plexus palatinus'tan çıkan kolların fissura palatina'dan geçerek plexus venosus nasalis ile, rostral tarafta da inciciv dişlerin caudal'inden apex nasi'ye uzanan kollarla v. labialis superior ile anastomoz yaptığı belirlendi. Plexus palatinus'tan orijin alan vv. palatinae'nin os palatinum'un lamina perpendicularis'inin medial tarafından geçerek v. palatina descendens'e açıldığı saptandı. Her iki cavum nasi'deki concha nasalis dorsalis'lere ait venöz plexus'ların apex nasi'de, concha nasalis ventralis'lere ait venöz plexus'ların da cartilago septi nasi'nin caudal'inde birbirleriyle birleştikleri görüldü. Ayrıca concha nasalis ventralis'e ait venöz plexus'un choana'da v. palatina descendens ile güçlü bir amastomoz şekillendirdiği gözlendi.

Anahtar Sözcükler: Vena maxillaris, tavşan, morfometri, anatomi

Introduction

Metabolic wastes and CO_2 are carried to the capillaries from tissues by thin walled venulas. From here on, the venulas that collect the blood connect with each other, thus forming the veins (1).

Veins forming more anastomoses than arteries (1) create the ophthalmic plexus, the nasal plexus, the palatine plexus and the pterygoid plexus in the cranium (1-3).

The venous blood of intracranial circulation is passed to the maxillary vein, the occipital vein and the ventral internal vertebral plexus via the emissary vein (4,5). The auricular veins in rabbits are prominent and suitable for injections (6).

Despite the detailed information available on arteries in textbooks, information on veins is fairly limited. It is reported that the venous drainage of the cranium and the neck area is provided by the internal and external jugular veins in rabbits as in rats and dogs (7-11). In rabbits, the auricular veins that are suitable for intravenous injections open to the maxillary vein; therefore the maxillary vein, being one of the main contributors to the formation of the external jugular vein and also collecting the venous blood of the deep part of the cranium, gains further importance in these species. The aim of this study was to investigate the distribution of the maxillary vein in more detail and the contribution of its branches to form this vein.

Materials and Methods

In this study, 15 adult New Zealand rabbits weighing 2968 ± 35.53 g were used. Animals were anesthetized with 5 mg/kg xylazine and 35 mg/kg ketamine intramuscularly. Blood in the cranial veins was removed by injecting a saline solution from the common carotid artery. The external jugular vein was ligated prior to injecting blue latex to 10 rabbits and blue Batson's No. 17 to 5 rabbits through the maxillary vein. Rabbits were then left for 24 hours in order to let the latex harden and then they were transferred to 10% formaldehyde solution and dissected as required. Rabbits that were injected with Batson's No. 17 were kept in 33% KOH solution for 48 hours and corrosion slides were prepared.

The diameters of the veins were measured with a digital dial caliper. Differences in the diameter between the left and right side veins were analyzed statistically using Student's t-test (12).

Results

The distribution of the maxillary vein in rabbits injected with latex was compared with the corrosion casts in this study and the findings were recorded. Diameters of the veins that eventually form the maxillary vein are given in the Table. Differences between the diameters of the veins on the left and the right side were not statistically significant in either corrosion casts or dissected specimens.

Table. The diameters of the veins that formed the maxillary vein in rabbits.

	Diameter, mm n=30	
	x	Sx
Maxillary vein	3.90	0.04
Caudal auricular vein	2.20	0.02
Superficial temporal vein	2.27	0.03
Transverse facial vein	1.35	0.01
Rostral auricular vein	1.44	0.01
Lateral auricular vein	1.29	0.01
Deep auricular vein	1.78	0.01
Intermediate auricular vein	0.93	0.01
Ventral masseteric vein	1.38	0.02
Dorsal external ophthalmic vein	1.37	0.03
Ascending pharyngeal vein	2.28	0.03
Pterygoid plexus	2.64	0.03
Deep temporal vein	0.92	0.02
Inferior alveolar vein	0.69	0.01
Masseteric vein	0.66	0.01

It was observed that the *maxillary* vein was formed by the conjunction of the temporal vein, the pterygoid plexus, the ventral and the caudal auricular vein on the caudal border of the ramus mandibulae. It was also determined that it continues along the ventral side of the parotid gland in the ventrocaudal direction and connects with the linguofacial vein on the caudal side of the angulus mandibulae and opens to the external jugular vein (Figures 1/a, 2/a, 3/a).

The *caudal auricular* vein was found to be formed by conjunction of the deep auricular, the intermediate auricular and the lateral auricular veins at the basis of the

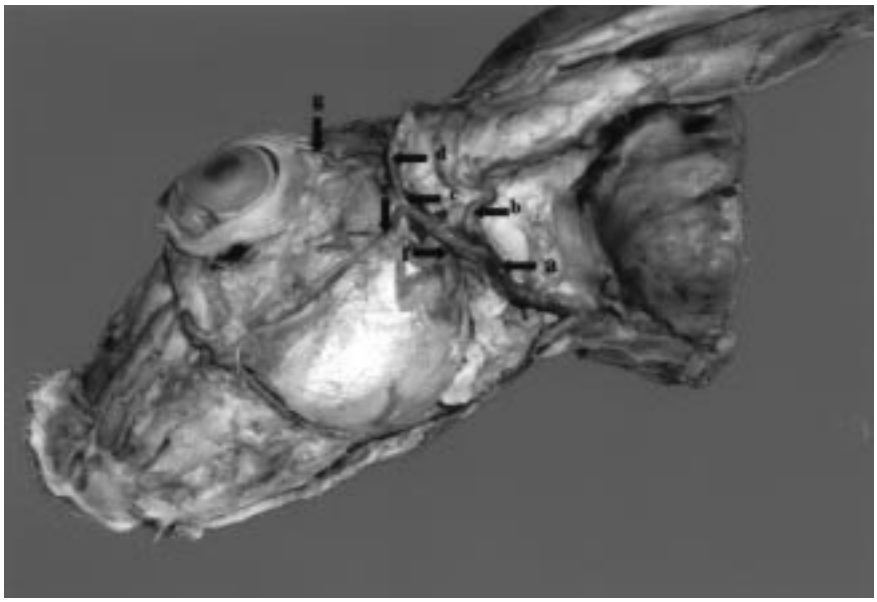

Figure 1. The appearance of the superficial distribution of the maxillary vein on the left side in rabbits injected with latex.
a- maxillary vein, b- caudal auricular vein, c- superficial temporal vein, d- rostral auricular vein, e- transverse facial vein, f- ventral masseteric vein, g- dorsal external ophthalmic vein.

auricula. It courses ventrally along the caudal border of the parotid gland before opening to the maxillary vein. Along its way, one or two branches coming out of parotid gland join the vein (Figures 1/b, 2/b, 3/b).

The *lateral auricular vein* originates from the apex of the auricula and continues along the cranial rim towards the basis of the ear before opening to the caudal auricular vein. It forms an anastomosis with the intermediate auricular vein at the apex of the ear.

The *intermediate auricular vein* originates from the apex of the ear, continuing caudoventrally and opens to the terminal part of the deep auricular vein.

The *deep auricular vein* originates from the caudal part of the ear and takes part in the formation of the caudal auricular vein at the caudoventral part of the bases of the ear.

The *ventral masseteric vein* was formed by the conjunction of the numerous branches originating from the caudoventral part of the masseteric muscle; this vein opens to the maxillary vein on the caudal part of the ascending pharyngeal vein (Figures 1/f, 2/i).

It was observed that the *superficial temporal vein* was formed on the rostral side of the external auditory meatus by the conjunction of the two branches arriving from the rostral and the caudal sides. Being thicker, the rostral branch is the continuation of the dorsal external ophthalmic vein and receives the superior palpebral vein from the upper eyelid. It was determined that the caudal branch was the continuation of the stylomastoid vein which leaves the cavum cranii through the stylomastoid foramen. These two branches of the superficial temporal vein join together and continue ventrally before opening to the maxillary vein. Along its way it receives a branch from the rostral auricular vein, the transverse facial vein and the parotid gland (Figures 1/c, 2/c, 3/c).

The *rostral auricular vein* originates from the base of the ear and continues on the rostroventral direction and opens to the caudal part of the superficial temporal vein just before the transverse facial vein (Figure 1/d).

The *transverse facial vein* continues as two parallel branches on the ventral and the dorsal sides of the crista facialis over the masseteric muscle and the two branches join together before opening to the rostral section of the superficial temporal vein. It forms an anastomosis on the front side over the masseteric muscle with a branch originating from the facial vein. A branch coming out of the dorsal branch continues ventrally through the depths of the masseteric muscle and forms an anastomosis with another branch coming out of the deep facial vein. It was also observed that seven and a single masseteric branches join the dorsal and the ventral branches of the transverse facial vein, respectively (Figures 1/e, 2/d, 3/d).

After separating from the ophthalmic plexus, the *dorsal external ophthalmic vein* continues in the dorsocaudal direction and, by turning caudally at the lateral side of the orbit, takes part in the formation of the superficial temporal vein (Figures 1/g, 3/e).

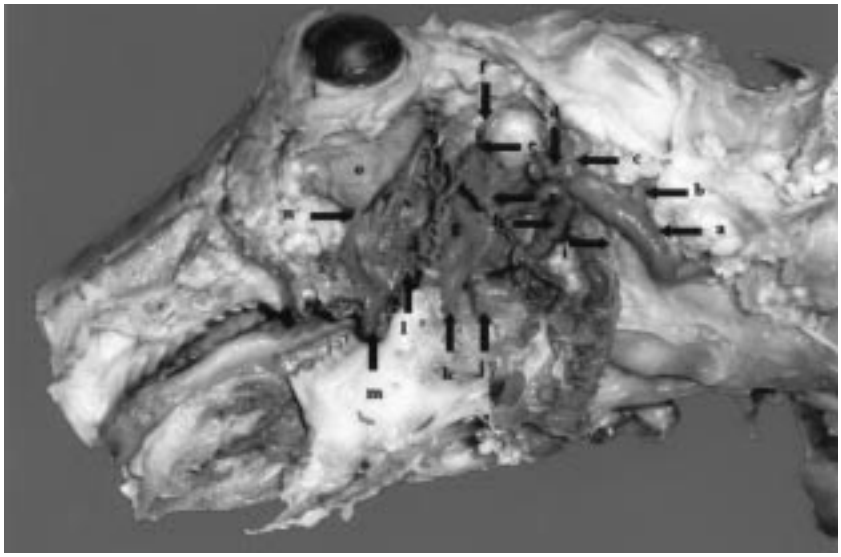

Figure 2. The appearance of the distribution of the maxillary vein on the left side in rabbits injected with latex.
a- maxillary vein, b- caudal auricular vein, c- superficial temporal vein, d- transverse facial vein, e- deep temporal vein, f- temporomandibular articular veins, g- pterygoid plexus, h-ascending pharyngeal vein, i- ventral masseteric vein, j- inferior alveolar vein, k- connecting branch from lingual vein to pterygoid plexus, l- connecting branch from deep facial vein to pterygoid plexus, m- deep facial vein, n- ventral external ophthalmic vein, o- ophthalmic plexus.

The *ophthalmic plexus* was formed by the conjunction of the vorticosa veins, the lacrimal vein, the muscular branches and the external ethmoidal vein at the medial side of the bulbus oculi. This cone-shaped structure had the appearance of a sinus. It was also observed that the supraorbital vein, the ventral external ophthalmic vein and the dorsal external ophthalmic vein all originated from this plexus (Figures 2/o, 3/m).

The *vorticosa veins* were formed by the conjunction of the conjunctival veins coming from the conjunctivas and the branches coming from the sclera; these veins open to the ophthalmic plexus.

The *lacrimal vein* left the lacrimal gland as two thin branches and it opens to the ophthalmic plexus.

The *muscular branches* came from the orbital muscles and congregate before joining the ophthalmic plexus.

The *external ethmoidal vein* came from the cavum nasi and passed through the lamina cribrosa and arrived at the ethmoidal fossa. They made an anastomosis with the rostral terminal veins of the dorsal sagittal sinus and, going through the ethmoidal foramen, join the ophthalmic plexus.

The *pterygoid plexus* is formed between the medial and the lateral pterygoid muscles by the conjunction of the pterygoid veins, the inferior alveolar vein, the masseteric vein, the deep temporal vein, the temporomandibular articular veins and the palatine veins. It continues caudally as the maxillary vein. The pterygoid plexus forms connections with the branches coming from the deep facial vein, the superficial temporal vein and the lingual vein (Figures 2/f, 3/r).

The *ascending pharyngeal vein* started as a strong cranial and a weak caudal branch; the cranial branch of the vein forms a pharyngeal plexus over the pharynx. The pharyngeal plexus forms a strong anastomosis with the pterygoid plexus. Along its continuation towards the caudal it gives a thin branch to each the medial pterygoid muscle and the radix linguae, before joining the caudal branch coming from the larynx. It was determined that the caudal branch originated from the larynx cartilages. It was also observed that the vein joins the cranial branch in the medial face of the ramus mandibulae before giving out two branches to the medial pterygoid muscle. These branches form anastomoses with the masseteric vein and further open to the maxillary vein on the caudal border of the ramus mandibulae at approximately 1 cm on the ventral side of the temporomandibular joint. The diameter of pharyngeal branch measured 1.86 mm; the diameter of laryngeal branch was 1.45 mm (Figures 2/h, 3/f).

The *pterygoid vein* came from the medial and lateral pterygoid muscles and takes part in the formation of the pterygoid plexus. These veins form anastomoses with the ventral masseteric vein.

The *mental vein* joins with the inferior labial vein at the mental foramen and, going through the mental foramen, passes over to the mandibular canal and continues as the inferior alveolar vein.

The *inferior alveolar vein* was determined as the continuation of the mental vein in the mandibular canal. It receives dental veins from the lower jaw while in the mandibular canal and, passing through the mandibular foramen, joins the ventral part of the pterygoid plexus (Figures 2/j, 3/i).

The *masseteric vein* comes from the depths of the masseteric muscle and joins the pterygoid plexus around the temporomandibular joint. It forms anastomoses with the deep facial vein and the transverse facial vein. It also forms an anastomosis with the temporomandibular articular veins caudodorsally.

The *deep temporal vein* starts as branches coming out of the temporal muscle; this vein joins the temporomandibular articular veins and opens to the maxillary vein. The vein turns towards the lateral side of the ramus mandibulae at the rostral part of the temporomandibular joint and joins the temporomandibular articular veins before continuing ventrally to join the dorsal branch of the transverse facial vein (Figures 2/e, 3/h).

The *temporomandibular articular veins*, coming from the temporomandibular joint, open to the deep temporal vein and join the masseteric vein in this region. This vein forms an anastomosis with a branch continuing ventrally from the superficial temporal vein (Figures 2/f, 3/f).

Numerous branches that come out of the *palatine veins* on either side make an anastomosis and form the palatine plexus in the submucosa of the palatum durum. Branches that leave the plexus pass through the fissura palatine and connect with the nasal venous plexus in the nasal cavity. Furthermore, few branches that leave the palatine plexus pass through the caudal part of the incisive teeth and form an anastomosis with the superior labial vein. The palatine veins pass through the medial side of the lamina perpendicularis of the palatine bone towards the caudal and open to the descending palatine vein.

The palatine veins form a strong anastomosis in the choana with the nasal veins, which originate from the ventral nasal concha and join on the caudal side of the cartilago septi nasi. From there, the nasal veins that come from both nasal cavities continue caudally on the ventral side of the basisphenoid and the basioccipital. These form an anastomosis with the internal vertebral venous plexus on the ventral side of the atlantooccipital joint and from there they continue as a single vein towards the caudal on the ventral side of vertebrae as the median colli vein (Figures 3/n, 3/o).

Draining the caudal part of the nasal cavity, the *sphenopalatine vein* forms an anastomosis with the branches of the palatine veins. It leaves the nasal cavity through the sphenopalatine foramen and opens to the descending palatine vein as a thin vein caudally.

The *infraorbital vein* forms an anastomosis with the superior labial vein at the infraorbital foramen. After entering the infraorbital foramen it continues caudally in the infraorbital canal while receiving the dental veins from the upper jaw teeth. It leaves the canal at the pterygopalatine fossa through the maxillary foramen and

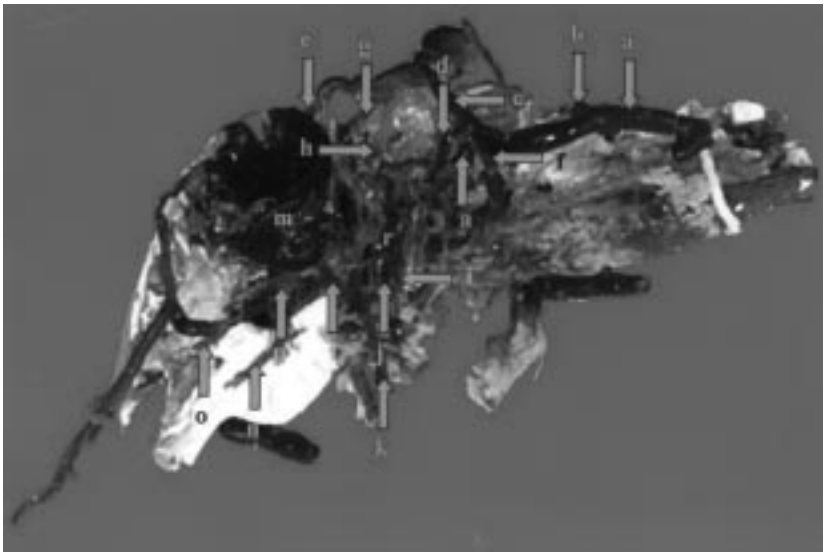

Figure 3. The appearance of the distribution of the maxillary vein on the left side in the corrosion cast of rabbits.
a- maxillary vein, b- caudal auricular vein, c- superficial temporal vein, d- transverse facial vein, e- dorsal external ophthalmic vein, f- ascending pharyngeal vein, g- temporomandibular articular veins, h- deep temporal vein, i- inferior alveolar vein, j- connecting branch from lingual vein to pterygoid plexus, k- deep facial vein, l- ventral external ophthalmic vein, m- ophthalmic plexus, n- palatine plexus, o-nasal venous plexus, p- descending palatine vein, r- pterygoid plexus.

opens to the descending palatine vein as a thin vein together with the sphenopalatine vein.

Discussion

Many researchers report that the maxillary vein in mammalian species is formed by the conjunction of the caudal auricular vein, the ventral masseteric vein, the superficial temporal vein, the pterygoid plexus and the ascending pharyngeal vein on the caudomedial part of the ramus mandibulae (1,3,13-15). In this study it was observed that the formation of the maxillary vein was very similar to this description. According to our estimation based on the measured diameters of the branches (Table) that form the vein, the pterygoid plexus, the superficial temporal vein, the ascending pharyngeal vein, the caudal auricular vein and the ventral masseteric vein provided 25%, 21%, 21%, 20% and 13% of the venous blood of the maxillary vein, respectively.

Various researchers report that the venous drainage of the auricula is provided by the caudal auricular vein and the rostral auricular vein (1,3,14). The present study supports the literature on the formation of the vessels that drain the auricula. Results of estimations of the diameter of the vessels showed that the caudal auricular vein was 35% thicker than the rostral auricular vein. In addition, 32%, 23% and 45% of the venous blood coming to the caudal auricular vein was provided by the lateral auricular vein, the intermediate auricular vein and the deep auricular vein, respectively.

As mentioned in the current literature (1,3,16), the transverse facial vein was formed by the conjunction of the dorsal and the ventral branches and forms an anastomosis with the facial vein rostrally. It was determined that the transverse facial vein provided 40% drainage to the masseteric muscle. Other vessels that drained this muscle were the ventral masseteric vein (41%) continuing caudoventrally and the masseteric vein (19%) going caudodorsally.

As reported by Nur (3), the ascending pharyngeal vein consisted of two branches. It was estimated that 56% of the venous blood of the vein was provided by the pharyngeal branch and 44% was provided by the laryngeal branch (Table).

In various papers it has been reported that the infraorbital vein opened to the pterygoid plexus in cats (14) and in rabbits (3) and to the deep facial vein in other mammalian species (14). Contrary to these reports, it was observed that the infraorbital vein opened to the descending palatine vein together with the sphenopalatine vein.

Ibrahim (17) reported that in rabbits the sphenopalatine vein opened to the descending palatine vein and Nur (3) reported that it provided the venous drainage of the nasal cavity and opened to the pterygoid plexus in rabbits. Sisson and Grossman (18) reported that in horses the sphenopalatine vein opened up to the deep facial vein and Nickel et al. (14) reported that it formed a rich venous plexus in the septum nasi and the nasal concha in all domestic species.

In this study, the sphenopalatine vein was observed to be a thin vein that opened to the descending palatine vein and, as reported by Ibrahim (17), provided the drainage of the small caudal area of the nasal cavity. Nur (3) reported that in rabbits the major palatine vein and sometimes the minor palatine vein passed through the palatine canal and opened to the descending palatine vein. Nickel et al. (14), however, reported that the major palatine vein is absent in domestic species and the other passed through the palatine canal in small ruminants.

In this study it was determined that the palatine veins that originated from the palatine plexus passed through the medial face of the lamina perpendicularis of the palatine bone and opened up to the descending palatine vein.

It was reported that, in the domestic animals, the palatine plexus makes connections with the nasal venous plexus with the branches that pass through the palatine fissure (14,15). Nur (3) reported that the branches that passed through the interincisive fissure provided this connection. However, Ibrahim (17) reported that this connection was provided by 10-15 small branches, which passed through the holes in the nasal process in the maxilla.

In this study it was determined that the palatine plexus formed an anastomosis with the nasal venous plexus via the branches that passed through the palatine fissure. Furthermore, the nasal venous plexus of both nasal cavities joined on the caudal part of the cartilago septi nasi and formed a strong anastomosis with the descending palatine vein at the choana, which has not been described in the current literature.

In conclusion, the distribution of the branches that form the maxillary vein and their interconnections are investigated. Also the percentage of contribution of these veins to the venous blood of the maxillary vein according to the measured diameters of the vessels is determined.

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