Stereological Studies on Several Ducts and Vessels
By Injection Method of Acrylic Resin

XXI. On the posterior superior alveolar, the infraorbital and the sphenopalatine arteries of Macacus cynomolgos, laying emphasis on the maxillary sinus and its vicinity*

By

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(With 41 Figures in 5 Plates)

Preface

The maxillary sinus of the primate plays a role as a resonator as well as a humidifier of air in the nasal cavity. The sinus is surrounded by a pretty thick wall of the maxillary bone and supplied by fine arterial branches which come from a few arterial resources running in and on the bony wall. Usually, these resources are the posterior superior alveolar, the infraorbital and the sphenopalatine arteries in the Macacus cynomolgos.

The observation on the sphenopalatine artery in some mammals was performed in detail by Ozaki (1968), including the R. sinus maxillaris of the artery.

The present paper will deal with arterial supplies of the maxillary sinus and its vicinity and of the upper teeth and their periodontium which have enormously concerned with them. Stereological studies of the above-mentioned arteries are made by means of the plastic corrosion and dissection specimens.

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**Materials and Methods**

Animals used for observations were 20 monkeys. After they were sacrificed by depletion, colloidal acrylic resin was injected through cannulae inserted into the common carotid arteries by the injection method of acrylic resin by Taniguchi, Ohta and TAJIRI (1952 and 1955). Soft tissues of the injected heads were dissolved away with sodium hydroxide solution to make plastic corrosion specimens, while several injected heads were preserved in 10% formalin for dissection.

Dissection and observation of the corrosion specimens were performed under the binocular magnifier and microscope.

**Observations**

§ Distributing arterial branches

Distributing branches to the maxillary sinus and its vicinity are given off from the posterior superior alveolar, the infraorbital and the sphenopalatine arteries.

The maxillary artery through the pterygomaxillary fissure into the pterygopalatine fossa divides into two terminal branches (fig. 1). The medial branch turns to the descending palatine artery running forward and downward in front of the Foramen rotundum. The lateral one enters the alveolar foramen as the posterior superior alveolar artery running forward and slightly laterally (fig. 2). The infraorbital artery is commonly ramified from the superior wall of the posterior superior alveolar (fig. 20), and the sphenopalatine from the superior wall of the descending palatine (fig. 29).

I. The posterior superior alveolar artery

For the convenience of the description, the artery is divided into three portions: The beginning portion, from the origin to the alveolar foramen; the maxillary portion, in the posterior superior alveolar canal; the terminal portion.

General course of the artery is as follows (fig. 3):

The artery runs horizontally forward or downward and forward in the posterior superior alveolar canal making a large curve along the convexity of the maxillary bone. It bends upward and slightly medially, distal to the canine, and reaches the root apex of the central
incisor beyond the apex of the canine, anastomosing (c. 0.14 mm) with the ascending terminal branch of the greater palatine artery (Castelli and Huelke, 1965).

A. The beginning portion
   The artery (0.45–0.81, M. 0.64 mm), in all 40 sides observed, arises from the anterior wall of the maxillary artery in the pterygopalatine fossa and runs forward and slightly laterally to enter the alveolar foramen near the inferior margin of the pterygomaxillary fissure.
   No branch is observed in this portion.

B. The maxillary portion
   The very moment the artery (0.31–0.63, M. 0.39 mm) enters the alveolar foramen, it separates the infraorbital artery from its superior wall and runs forward horizontally or forward and downward in the posterior superior alveolar canal.
   The lateral wall of the canal is pretty thick. The medial wall on the other hand is lacking in bone here and there, being covered with the mucoperiosteum of the maxillary sinus. Therefore the artery goes forward along the mucoperiosteum giving twigs to it (fig. 5).
   
   Branches:
   (1) The accessory posterior superior alveolar artery (figs. 6 and 7)
   The artery (0.15–0.45, M. 0.29 mm) is observed in 18 cases. After the posterior superior alveolar artery gives off the infraorbital artery from its superior wall, it also separates an artery which is as almost thick as itself from its medial wall, about 1.0 mm proximal or 3.6 mm distal to the origin of the infraorbital artery in the canal. The artery is named the accessory posterior superior alveolar artery. It runs forward and slightly downward in the maxillary bone inferior to the maxillary sinus and gives branches to the pulps, the periodontal membranes and the interalveolar and intraradicular septa of the molars. It is finally distributed to the gingiva attached to the internal alveolar plate.

   (2) The alveolar-dental branches
   The posterior superior alveolar artery runs forward above buccal roots of the molars. Throughout its course, it gives off 5–7 alveolar-dental branches (0.12–0.30, M. 0.23 mm) (Castelli and Huelke).
   Features of the branches are as follows:
   (a) In 24 cases, the alveolar-dental branches are together or
separately given off from the inferior or lateral wall of the posterior superior alveolar artery, distal to the origin of the accessory posterior superior alveolar artery (fig. 8). They together run forward like a brush between the posterior superior alveolar and apices of the molars, in parallel with the artery, leading through the spongy substance up to the premolars. Throughout their courses, they give off twigs which supply the pulps, the periodontal membranes and the interalveolar and inter-radicular septa of the premolars (fig. 9). The parent branches finally are distributed to the gingiva attached to the internal alveolar plate of the maxillary bone.

In this feature, the accessory posterior superior alveolar artery is not observed. In place of the artery, branches to the palatal roots and their surroundings are given off from the medial or inferior wall of the posterior superior alveolar artery (fig. 9). These branches also separate twigs which supply the gingivae, the periodontal membranes and the interalveolar and interradicular septa of the molars.

For the buccal portion of the molars and premolars, twigs are given off from the alveolar-dental branches.

(b) In 16 cases, the alveolar-dental branches are given off at almost regular intervals from the inferior wall of the posterior superior alveolar artery. Three or four proximal branches of them are distributed to the molars and the other distal branches to the premolars. The latter are sometimes given off from the former (fig. 10).

They run forward and downward in the external alveolar plate of the molars and premolars leading through the spongy substance. Their terminations supply the periodontal membranes of buccal roots and the gingiva attached to the external alveolar plate. Throughout their courses, they give off twigs which supply the pulps, the periodontal membranes, the interalveolar and inter-radicular septa of the molars and premolars (figs. 11, 12 and 13).

In this feature, the branches being distributed to the pulps and the surroundings of the molar roots are given off from the accessory posterior superior alveolar artery (fig. 10).

The alveolar-dental branches to the premolars are distributed to the pulps, the periodontal membranes, the interalveolar and interradicular septa of the premolars (fig. 14). The branches also give off twigs which supply the surroundings of the palatal roots.
Arteries around the Maxillary Sinus in Macacus

of the molars and premolars (fig. 16).

C. The terminal portion (figs. 15, 17, 18 and 19)

The posterior superior alveolar artery makes an arterial plexus around the root apex of the canine. The plexus gives off twigs which are distributed to the pulp, the periodontal membrane, the external and internal alveolar plates and the gingiva of the canine.

As to the central and lateral incisors, the ascending terminal branch of the greater palatine artery ascends in the internal alveolar plate of the incisive bone and makes an arterial plexus around the incisors. The plexus is in communication with the plexus around the canine root and gives twigs to the pulps, the periodontal membranes, the alveoli and gingivae of the incisors.

II. The infraorbital artery

The artery is also divided into three portions: The beginning portion, from the origin to the orbita; the orbital portion, in the orbital groove; the portion in the infraorbital canal, from the beginning of the canal to the infraorbital foramen.

General course of the artery is as follows (fig. 23):

The artery enters the infraorbital groove and runs forward along the groove. Just before entering the infraorbital canal, the artery separates into three or four branches and each runs independently through the canal.

A. The beginning portion

The artery (0.25–0.45, M. 0.33 mm) separates commonly from the posterior superior alveolar artery in front of the alveolar foramen in 36 cases and in the alveolar canal in 4 cases. Speaking of that in detail, the artery arises from the superior or superomedial wall of the posterior superior alveolar artery in 28 cases (fig. 20), from the medial wall in 8 cases and from the lateral wall in 2 cases. In one case, the artery separates from the lateral wall of the sphenopalatine artery (fig. 21) and in one case from a branch of the ophthalmic artery.

The infraorbital artery arising in the posterior superior alveolar canal runs backward once and then forward and slightly medially to enter the infraorbital groove after passing out of the alveolar foramen (fig. 22).
B. The orbital portion

In all cases observed, the infraorbital artery (0.19–0.43, M. 0.30 mm) runs forward first along the infraorbital groove which is scarce of impression on the bone. It reaches the nasolacrimal canal running medially in front of the medialmost of the infraorbital canals. The artery divides into three or four infraorbital branches. The ramification is commonly observed behind the inferior orbital margin except 2 cases where it is found near the origin of the artery from the posterior superior alveolar. Each branch arises from the lateral or superior wall of the parent artery and enters each of 3 or 4 canals running forward (fig. 23).

As to the canal, the second one from the medial side is ordinarily widest, therefore the second infraorbital branch (0.15–0.31, M. 0.22 mm) is thickest.

Branches:

(1) R. nasolacrimalis (figs. 24 and 25)

The ramus (0.12–0.31, M. 0.19 mm), the course continuation of the infraorbital artery, runs medially in front of the medialmost canal up to the nasolacrimal canal through a small foramen in the maxillo-lacrimal suture. The branch gives off twigs (0.10–0.19, M. 0.13 mm) to the upper part of the mucous membrane of the canal from its superior wall and also twigs (0.12–0.19, M. 0.15 mm) to its lower part as well as the nasal aperture of the canal from its inferior wall.

The ramus anastomoses (c. 0.12 mm) with the branches to the inferior oblique muscle of the ophthalmic artery before the ramus enters the small foramen near the maxillo-lacrimal suture (fig. 26).

(2) R. sinus maxillaris (fig. 27)

The ramus (0.12–0.15, M. 0.14 mm) is given off from the inferior wall of the infraorbital artery near the medial second one of the infraorbital canals. The ramus runs downward through the incomplete maxillo-ethmoidal suture and is distributed to the mucoperiosteum of the superior wall of the maxillary sinus.

C. The portion in the infraorbital canal

Each of three or four ramified infraorbital branches (0.12–0.25, M. 0.16 mm) passes independently through each infraorbital canal.

Branches:

(1) R. sinus maxillaris

The inferior wall of the second infraorbital canal from the medial side is lacking in bone. So the ramus is directly attached to the
mucoperiosteum of the maxillary sinus. It (0.11–0.14, M. 0.12 mm) runs forward and downward through this part and is distributed to the mucoperiosteum of the supero-anterior wall of the maxillary sinus.

(2) Alveolar twig (fig. 28)

In the maxillary bone of the monkey, the anterior superior alveolar canal is not observed, and the anterior superior alveolar artery is not recognized. In place of the artery, a twig (c. 0.12 mm) arising from the superior wall of the main infraorbital branch runs downward in the maxillary bone leading through the spongy substance and is distributed to the external alveolar plate of the canine.

III. The sphenopalatine artery

The artery is also divided into three portions: The beginning portion, from the beginning to the appearance into the nasal cavity; the posterior portion, in the nasal cavity; the terminal portion.

General course of the artery is as follows:
The artery runs upward once, then forward and downward (fig. 29). It appears in the nasal cavity behind the inferior nasal concha passing through a small canal being located between the maxillary and the palatine bones. It continues forward on the lateral wall of the middle nasal meatus up to the nasal vestibule.

A. The beginning portion

A common trunk (0.45–1.05, M. 0.82 mm) of the sphenopalatine and descending palatine arteries makes an acute upward arch in the pterygopalatine fossa to fit the palatine canal, the orifice of which protrudes into the fossa. Then, the trunk runs infero-anteriorly into the palatine canal (fig. 29).

The sphenopalatine artery (0.40–0.59, M. 0.56 mm) leaves the superior wall of the descending palatine in 36 cases (fig. 29), and the medial wall of a common trunk of the posterior superior alveolar and infraorbital arteries in 4 cases, in the pterygopalatine fossa or palatine canal (figs. 30 and 32).

The sphenopalatine artery runs upward about 3.0 mm and gives off an artery, the A. conchalis nasalis mediae, from its superior wall at the sphenopalatine foramen. The sphenopalatine artery, without passing through the foramen, runs forward and downward in a
small canal lying between the maxillary bone and the perpendicular plate of the palatine bone. The artery finally appears out of a small foramen into the nasal cavity behind the inferior nasal concha (fig. 31).

In two cases of all, the artery leaving the descending palatine in the palatine canal, goes out of the canal, taking a supero-posterior course, into the pterygopalatine fossa and appears into the nasal cavity through the sphenopalatine foramen (fig. 32).

The artery arising from the common trunk of the posterior superior alveolar and infraorbital arteries runs infero-anteriorly in the shape of an acute S curve and appears into the nasal cavity through the small canal above-mentioned (fig. 30).

Branches:

(1) R. nasalis septi

At the posterior part of the middle nasal meatus, the artery (0.20–0.37, M. 0.35 mm) arises from the superior or medial wall of the sphenopalatine artery in 22 cases (figs. 33 and 36), from the superior wall of the common trunk of the sphenopalatine and descending palatine arteries in 6 cases (fig. 37), from the superior wall of the descending palatine artery in 4 cases and from a branch of the ophthalmic artery in 2 cases (fig. 34).

The artery which runs forward and upward arrives at the nasal septum through the postero-inferior end of the middle nasal meatus, and continues forward. Throughout its course, the artery gives off the R. nasalis septi medius (0.15–0.29, M. 0.23 mm) (Ozaki, 1968) to the supero-anterior part of the nasal septum.

The artery continues forward as the R. nasalis septi anterior (0.18–0.30, M. 0.25 mm) and anastomoses (c. 0.12 mm) with the R. nasalis of the greater palatine artery above the incisive canal. Both nasales septi anterior and medius make an arterial network on the septum with the R. nasalis of the posterior ethmoidal artery (Shimizu, 1968), that is, the distributing area of both is an inferior third of the septum or an inferior half at most.

(2) A. conchalis nasalis mediae (Branch to the ethmoturbinalia)

The artery (0.29–0.45, M. 0.35 mm) arises from the superior wall of the sphenopalatine artery at its appearance into the nasal cavity in the posterior part of the middle nasal meatus in 24 cases (fig. 36), from the superior wall of the sphenopalatine at the sphenopalatine foramen in 10 cases (fig. 37), from the superior wall of the descending palatine artery in the palatine canal in 4 cases (fig. 38) and from a
branch of the ophthalmic artery at the posterior part of the middle
nasal meatus in 2 cases (fig. 34).

The artery runs forward and upward and reaches the posterior
depth of the middle nasal concha. Then, it continues forward and
upward up to the posterior part of the superior nasal meatus. The
artery arising at the sphenopalatine foramen runs upward once,
then forward through the superior part of the foramen (figs. 32 and
37). The artery arising in the palatine canal runs backward once,
then appears into the nasal cavity running forward and upward
after passing through the canal.

Branches are seen as follows:

(a) Medial branch (fig. 36)

The branch (0.15–0.40, M. 0.35 mm) arises from the anterior
wall of the A. conchalis nasalis mediae at the posterior end of
the middle nasal concha and runs forward to supply its medial
surface.

(b) Lateral branches (fig. 36)

The branches (0.15–0.43, M. 0.35 mm) are 1 or 2 in number.
They arise from the anterior or lateral wall of the A. conchalis
nasalis mediae at the posterior end of the middle nasal concha
and run forward to supply its lateral surface.

(c) Rr. nasales parietales laterales (Branch to the lateral
wall of the superior nasal meatus) (fig. 36)

The branches (0.15–0.38, M. 0.31 mm) are observed two in
number. One of them arises from the posterior wall of the A.
conchalis nasalis mediae at the posterior end of the middle nasal
concha and runs backward and upward to supply the posterior
part of the lateral wall of the superior nasal meatus. The other,
the continuation of the A. conchalis nasalis mediae, comes to the
posterior end of the superior nasal meatus. It runs forward to
supply the same area.

B. The posterior portion

The sphenopalatine artery runs forward as the A. nasalis post-
erior lateralis along the inferior nasal conchal crest, then the lateral
wall of the middle nasal meatus.

Branches:

(1) R. nasalis parietalis inferior (figs. 31 and 39)
The ramus (0.08–0.09, M. 0.09 mm) arises from the inferior wall
of the sphenopalatine artery at the posterior end of the inferior nasal concha and runs forward and downward. It divides into two branches, the medial and the anterior. Both branches supply the inferior wall of the nasal cavity.

(2) R. conchalis nasalis inferioris (figs. 31 and 39)

The ramus (0.12–0.18, M. 0.15 mm) arises from the medial or inferior wall of the sphenopalatine artery distal to the origin of the R. nasalis parietalis inferior. It runs forward and downward and is mainly distributed to the medial surface of the inferior nasal concha. It also gives off a branch to the inferior wall of the nasal cavity.

(3) R. sinus maxillaris (figs. 31 and 39)

The ramus (0.18–0.22, M. 0.19 mm) arises from the superior wall of the sphenopalatine artery distal to the origin of the R. conchalis nasalis inferioris and runs upward. It divides into 2 or 3 which supply the mucoperiosteum of the medial wall of the maxillary sinus.

C. The terminal portion

The sphenopalatine artery (0.29–0.45, M. 0.40 mm) passes at the anterior end of the middle nasal concha up to the nasal vestibule. Giving off two to four branches at this area, it changes its course slightly forward and upward and spreads on the face, especially the superolateral portion of the external nasal aperture with peripheries of the facial artery (fig. 40).

Branches:
(1) R. infravestibularis (figs. 40 and 41)

The ramus (0.14–0.30, M. 0.25 mm) arises from the inferior wall of the sphenopalatine artery at the middle nasal meatus and runs forward and slightly downward. At the nasal vestibule, the ramus changes its course almost in parallel to the sphenopalatine artery. Throughout its course, it gives twigs to the incisive canal and an inferior half of the nasal vestibule.

(2) Rr. supravestibulares (figs. 40 and 41)

The rami (0.14–0.35, M. 0.28 mm) are two or three in number. One of them arises from the superior wall of the sphenopalatine artery in front of the middle nasal concha. It runs upward once and turns backward making a superoposterior curvature at the nasal vestibule to supply the lateral wall of the superior nasal meatus with
branches of the A. conchalis nasalis mediae and the anterior ethmoidal artery. Others arise from the superior or lateral wall of the sphenopalatine artery at the anterior part of the vestibule and run upward to supply a superior half of the vestibule with the R. nasalis parietalis lateralis.

§ Regional arterial supply of the maxillary sinus

So far, no description can be seen such as the morphological study on the maxillary sinus of this type of the Macacus cynomolgos. Accordingly, the present author makes an attempt to demarcate the sinus into four walls and two horns, prior to the observation of the arterial supply of the sinus.

1. The lateral wall

This wall is widest of all, shaped like a parallelogram, and can be divided into two parts by the zygomatic recess, the anterolateral and the posterolateral. The former made by the maxillary bone is narrower than the latter, the infratemporal part, which is redivided into the superior and inferior halves. The original wall of the maxillary bone of the superior half is very thin, but thickened by a suture of the zygomatic bone just like a wide squamous one. The inferior half is formed by the infratemporal surface of the maxillary bone.

2. The medial wall

This wall is the nasal surface of the maxillary bone, or the lateral wall of the nasal cavity. The surrounding margin of this wall is formed by the ethmoid, the maxillary and the palatine bones, but its central part, the maxillary hiatus, is made by the nasal mucous membrane. A very small aperture of the sinus opens on the superior end of this wall.

3. The superior wall

This wall is very thin. Its lateral half is formed by the orbital surface of the maxillary bone and its medial half by the orbital surface of the ethmoid bone.

4. The inferior wall

This wall is thick, shaped like a narrow ship's bottom, as if the wall could spread into the alveolar and palatine processes.
5. The anterior horn
This horn is made by a convergence of the above-mentioned four walls. It is not located beyond the root apex of the second premolar.

6. The posterior horn
This horn, made by a convergence of the above-mentioned four walls in front of the pterygopalatine fossa, shows an attractive shape in this monkey. Especially, the medial wall spreads backward, the inferior wall gradually directs its posterior end to the posterosuperior, and the medial and lateral walls make close to each other for forming this horn. Accordingly this horn is fairly sharp.

Distributing arterial branches to the maxillary sinus are given off from the posterior superior alveolar, the infraorbital and the sphenopalatine arteries.

Their distributing territories are shown under:
1. The lateral and inferior walls, the anterior and posterior horns
These walls and horns are supplied with the posterior superior alveolar and its accessory arteries.

2. The superior wall
The R. sinus maxillaris arising from the inferior wall of the infraorbital artery near the medial second of the infraorbital canals runs downward through the incomplete maxillo-ethmoidal suture and is distributed to the mucoperiosteum of the superior wall of the sinus.

The R. sinus maxillaris arising from the inferior wall of the infraorbital branch runs forward and downward through the bone-less part, being distributed to the mucoperiosteum of the antero-superior wall of the sinus.

3. The medial wall
The R. sinus maxillaris arising from the superior wall of the sphenopalatine artery runs upward within the nasal mucous membrane. Throughout its course, it gives off two or three twigs, each of which runs forward and backward to supply the mucous membrane surrounding the orifice of the sinus.

Summary and Discussion
So far, there have been no details of studies on the posterior superior alveolar, the infraorbital and the sphenopalatine arteries of
the Macacus cynomolgos, all of which are branches of the maxillary artery and important supply resources to the upper teeth and the nasal organ.

Lineback (1933) and Dyrd (1944) have studied the gross ramification of the external carotid artery of the rhesus monkey (Macaca mulatta). Castelli and Huelke (1965) have made pretty detailed observations on the branches of the external carotid artery of the rhesus monkey by four different techniques.

Now, the present author will try to discuss the observation on the above-mentioned arteries laying emphasis on the maxillary sinus and its vicinity on the acrylic corrosion specimens.

1. The maxillary artery in the pterygopalatine fossa

It has been described in the textbooks of the human anatomy that the posterior superior alveolar artery arose from the maxillary or infraorbital arteries at the maxillary tuber. Sichler (1952) stated that the posterior superior alveolar and the infraorbital arteries arose from the maxillary artery by a common trunk in the human. Hata (1967) stated that the posterior superior alveolar and the buccal arteries arose from the maxillary artery by a common trunk in the human.

The present author observed in the monkey that the artery through the pterygomaxillary fissure into the pterygopalatine fossa divided into the medial and lateral branches. The medial branch turned to the descending palatine artery running forward, and the lateral entered the alveolar foramen as the posterior superior alveolar artery running forward and slightly laterally.

2. The posterior superior alveolar artery

The artery commonly gave off the infraorbital artery within or before the posterior superior alveolar canal. It (M. 0.39 mm) was thicker than the infraorbital (M. 0.33 mm). The well-developed artery extended in succession from the alveolar foramen to the root apices like an arch, for any teeth was as well-developed as the maxillary bone because of the long snout of the primate. The artery cannot help growing to supply these organs.

Castelli et al. stated that the posterior superior alveolar artery continued forward in the maxilla above and lateral to the maxillary sinus. Throughout its course, alveolar-dental branches were given off which supplied the teeth and supporting tissues as far forward as the cuspid teeth. The present author found in addition that the
termination of the artery made an arterial plexus at the root apex of the canine.

The posterior superior alveolar canal of this monkey showed a characteristic feature that the medial wall of the canal was lacking in bone being covered with the mucoperiosteum of the maxillary sinus. And the artery went forward along the mucoperiosteum giving twigs to it.

Sicher stated in the human that the posterior superior alveolar artery, a fairly strong blood vessel, took a winding course over the convexity of the maxillary tuber, and running downward and forward, it was closely related to the bone and its periosteum.

The author found the accessory posterior superior alveolar artery which was not reported so far. The artery ran forward and slightly downward in the maxillary bone, the inferior wall of the maxillary sinus, supplying the adjacent structure of palatal roots of the molars and the mucoperiosteum being attached to the inferior wall of the sinus.

Castelli et al. stated that each alveolar-dental artery which was given off from the posterior superior alveolar artery divided into secondary branches which supplied the dental pulps, the periodontal membranes, and the interradicular and interdental septa. The author also observed such alveolar-dental branches arising from the posterior superior alveolar artery. Two features were found as to their arising from the artery, that is, one was that they were given off like a brush, the other was that they left at almost regular intervals.

Hata et al. (1965) stated in rabbit that the posterior superior alveolar artery gave off the three-branch set of the Rr. dentales—the pulpal, the periodontal and the gingivo-alveolar branches for each tooth almost regularly. But, in the monkey in this study, such a regular ramification could not be observed. The secondary branch of the posterior superior alveolar artery, the alveolar-dental branches or their twigs supplied the dental pulps, the periodontal membranes, the interalveolar and interradicular septa and the gingivae.

The ascending terminal branch of the greater palatine artery by Castelli et al. made a plexus at the root apices of the incisors. The author observed that the termination of the posterior superior alveolar artery made an arterial plexus at the root apex of the canine, and the plexus at the both canine and incisors communicated with each other.
3. The infraorbital artery

Castelli et al. stated that the infraorbital branches arose either from the posterior superior alveolar artery or from the sphenopalatine artery. The present author found in the monkey that the infraorbital artery arose from the posterior superior alveolar in 38 cases and from the sphenopalatine and ophthalmic arteries in each one case.

In the human, the infraorbital artery entered the orbit through the inferior orbital fissure and ran anteriorly in the infraorbital sulcus and then in the infraorbital canal.

In the monkey, the superior wall of the maxillary sinus was very thin, and its medial half was formed by the ethmoid bone and the lateral half by the maxillary bone. The infraorbital groove was not so deep as in the human, and the artery was under-developed. The inferior orbital fissure was also under-developed since the posterior end of the temporal surface of the zygomatic bone extended to the pterygopalatine fossa. The artery arose from the superior wall of the posterior superior alveolar artery, while in the human it arose from the maxillary. So, without entering the fissure, it ran forward along the groove, then running medially, it turned to the R. naso-lacrimalis. Therefore, the artery did not enter the infraorbital canal, and throughout its course, it gave off three or four infraorbital branches which ran through the canals.

Gray (1962) and Sichert stated in their textbooks the infraorbital artery sent small branches to the inferior muscles of the eyeball, the inferior straight and the inferior oblique muscles. The present author observed in the monkey a fine twig of the infraorbital artery being distributed to only the inferior oblique muscle.

Castelli et al. stated that the study of the cleared maxillae in the Macaque showed the absence of the anterior superior alveolar artery was supplied by the extension of the greater palatine artery upward into the anterior part of the maxillary bone. The present author also could not find the anterior superior alveolar artery. But, in addition to the extension of the greater palatine, it was observed that the alveolar twig arising from the infraorbital branch in the canal was distributed to the external alveolar plate of the canine.

4. The sphenopalatine artery

Ozaki (1968) stated in the human fetus that a common trunk between the sphenopalatine and the descending palatine arteries ran medioposteriorly and slightly upward from the orifice of the pterygopalatine fossa to the sphenopalatine foramen and passed through the
foramen medially. Sichert stated in the human that the sphenopalatine artery was the last of the terminal branches of the maxillary artery and passed from the uppermost part of the pterygopalatine fossa through the sphenopalatine foramen into the nasal cavity.

Caselli et al. stated in the rhesus monkey that the sphenopalatine artery appeared to be a direct continuation of the maxillary artery. It passed through the sphenopalatine foramen and, after a short course, gave rise to posterior nasal and descending palatine arteries.

In the Macacus cynomolgos in this study, a common trunk of the sphenopalatine and the descending palatine arteries was the direct continuation of the maxillary artery, and then ran downward to be the descending palatine artery through the palatine canal. The sphenopalatine artery by Caselli et al. might correspond to the common trunk in the present paper, and the posterior nasal artery stated by them to the sphenopalatine artery. The sphenopalatine artery in this thesis, without passing through the foramen, ran forward and downward within a small canal lying between the maxillary bone and the perpendicular plate of the palatine bone and then appeared in the nasal cavity out of a small foramen.

Caselli et al. stated that the posterior nasal arteries supplied almost all of the lateral nasal wall through superior and inferior branches. The superior branch was distributed to the middle nasal concha and meatus and the maxillary sinus. The inferior nasal branch supplied the inferior concha and meatus, and the floor of the nasal cavity. The superior nasal branch by them was the A. conchalis nasalis mediae in the present paper and the inferior nasal branch was the A. nasalis posterior lateralis.

Sichert stated in the human that close to the roof of the nasal cavity, the sphenopalatine artery divided into the lateral and septal branches. The posterior lateral nasal artery (A. nasalis posterior lateralis) divided on the lateral wall of the nasal cavity into branches which supplied the middle and upper nasal conchae and the mucous membrane in the corresponding nasal passage; smaller branches perforated the lateral nasal wall and reached the mucous membrane of the maxillary sinus. In the human, as Sichert stated, the R. sinus maxillaris arising from the branches to the middle concha was distributed to the mucous membrane of the maxillary sinus. By the present author, in the Macacus cynomolgos, throughout its forward course, the sphenopalatine artery itself gave off the A. conchalis nasalis mediae and the R. sinus maxillaris.
Negus (1958) stated in the human the blood vessel which supplied the maxillary sinus was derived from branches of the sphenopalatine artery, which entered through the ostium; irregular perforating branches also reached to it.

Ozaki stated the Rr. sinus maxillares in some mammals; in dog the ramus arose from the lateral or superior wall of the sphenopalatine and from the posterior, lateral or medial wall between beginnings of the nasalis conchalis inferioris and the inframaxilloturbinalis, and passed upward and divided into two which spread to the lateral wall of the recess and to the anterior and medial walls, respectively; in cat the ramus arose from the lateral wall of the sphenopalatine, 6.0–6.3 mm distal to the branching of the R. nasalis septi anterior, at the posterolateral corner of the recess, and passed supranteriorly on the lateral wall of it; in rabbit the rami, 3–5 in number, arose from the lateral or superior wall of the artery infralaterally, medial or distal to the branch to the ectoturbinalia in front of the medial wall of the sinus, and supplied the Gl. nasalis lateralis which lay between the anterior end of the sinus and the maxilloturbinal crest; in human fetus the A. nasalis septi divided into two, the R. nasalis septi anterior (corresponding to the A. nasalis posterior septi) and the R. nasalis septi medius.

Sicher stated in the human that the posterior septal artery reached the nasal septum over the roof of the nasal cavity and took a diagonal course downward and forward along the septum. After supplying branches to the nasal septum, the septal artery anastomosed with the nasopalatine branch of the major palatine artery. In the Macacus cynomolgos, the present author observed the same branch as human fetus, and these branches were distributed to the nasal septum with the posterior ethmoidal artery running downward on the septum.

Ozaki stated in human fetus the sphenopalatine bent forward at the posterior end of the inferior concha as the A. nasalis posterior lateralis and passed on the inferior concha up to the nasal vestibule, where it anastomosed with branches of the facial. In the Macacus cynomolgos in this paper, the artery ran forward on the middle meatus up to the nasal vestibule, not on the inferior concha as human fetus.
Conclusions

1. Stereological studies were accomplished by the acrylic resin injection method on the posterior superior alveolar, the infraorbital and the sphenopalatine arteries of the Macacus cynomolgus, laying emphasis on the maxillary sinus and its vicinity—their origins, ramifications and supplying territories.

2. The posterior superior alveolar artery was divided into the following portions:
   - The beginning portion, from the origin to the alveolar foramen; in all cases observed, the artery arose from the anterior wall of the maxillary artery in the pterygopalatine fossa and ran forward and slightly laterally to enter the alveolar foramen.
   - The maxillary portion, in the posterior superior alveolar canal; the artery ran forward and slightly downward in the canal.
   - Branches: Infraorbital artery, accessory posterior superior alveolar artery and alveolar-dental branches.

3. The infraorbital artery was divided into the following portions:
   - The beginning portion, from the origin to the orbita; the artery commonly arose from the superior wall of the posterior superior alveolar artery.
   - The orbital portion, in the orbital groove; the artery ran forward first along the infraorbital groove, then reached the nasolacrimal canal running medially in front of the medialmost of the infraorbital canals.
   - Branches: Infraorbital branches, R. nasolacrimalis and R. sinus maxillaris.
   - The portion of the infraorbital canal; each of three or four infraorbital branches arising from the lateral wall of the infraorbital artery passed through the infraorbital canal independently.
   - Branches: R. sinus maxillaris and alveolar twig.

4. The sphenopalatine artery was divided into the following portions:
   - The beginning portion, from the beginning to the appearance into the nasal cavity; the artery commonly arose from the superior wall of the descending palatine artery and without passing through the sphenopalatine foramen, it ran forward and downward in a small canal lying between the maxillary bone and the perpendicular plate of the palatine bone. It finally appeared out of a small foramen into
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the nasal cavity.

Branches: R. nasalis septi and A. conchalis nasalis mediae.

The posterior portion, in the nasal cavity; the artery ran forward as the A. nasalis posterior lateralis along the inferior nasal conchal crest, the lateral wall of the middle nasal meatus.

Branches: R. nasalis parietalis inferior, R. conchalis nasalis inferioris and R. sinus maxillaris.

The terminal portion; the artery changed its course forward and slightly upward at the nasal vestibule and spread on the superolateral portion of the external nasal aperture.

Branches: R. infravestibularis and Rr. supravestibulares.

5. The maxillary sinus was demarcated into four walls and two horns; the lateral, medial, superior and inferior walls, the anterior and posterior horns.

Distributing arterial branches to the maxillary sinus was given off from the posterior superior alveolar, the infraorbital and the sphenopalatine arteries.

The lateral and inferior walls, the anterior and posterior horns were supplied with the posterior superior alveolar and its accessory arteries. The superior wall was supplied with the Rr. sinus maxillares of the infraorbital artery and branch arising from the artery. The medial wall was supplied with the R. sinus maxillaris of the sphenopalatine artery.

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Literature cited


Explanation of Figures Key to Abbreviations

a Alveolar foramen
ad Alveolar-dental branch
ap Accessory posterior superior alveolar artery
cm A. conchalis nasalis mediae
d Descending palatine artery
i Infraorbital artery
ia Twig of interalveolar septa
ir Twig of interradicular septa
m Maxillary artery
Mb Maxillary bone
Ms Maxillary sinus
ns R. nasalis septi
p Posterior superior alveolar artery
pt Pulpal twig
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rn R. nasolacrimalis
s Sphenopalatine artery
sa R. nasalis septi anterior
sm R. nasalis septi medius
tb Ascending terminal branch of the greater palatine artery
~ Direction of snout

Plate I

Posterior superior alveolar artery (figs. 1-19)

Fig. 1. Lateral view of the terminal portion of the maxillary artery in the pterygo-palatine fossa. Buccal artery (x). Anterior deep temporal artery (O). C. ×1.8.

Fig. 2. Superior view of the beginning. C. ×2.0.

Fig. 3. General medial view of the posterior superior alveolar artery. C. ×1.8.

Fig. 4. Lateral view of the beginning portion. C. ×2.6.

Fig. 5. Medial view of the maxillary sinus. C. ×4.0.

Fig. 6. Lateral view of the maxillary portion. The accessory posterior superior alveolar artery arises from the medial wall (x) of the posterior superior alveolar artery. C. ×3.2.

Fig. 7. Medial view of the accessory posterior superior alveolar artery. C. ×3.2.

Fig. 8. Lateral view of the alveolar-dental branches. They are together given off from the inferior or lateral wall of the posterior superior alveolar artery like a brush. C. ×2.6.

Plate II

Figs. 9-14. Lateral view of the alveolar-dental branches.

Fig. 9. The alveolar-dental branches are given off from the medial or inferior wall of the posterior superior alveolar artery. Spongy substance of the maxillary bone (x). C. ×2.6.

Fig. 10. The alveolar-dental branches are given off at almost regular intervals. Canine (x). C. ×2.6.

Fig. 11. The termination of the alveolar-dental branch supplies the periodontal membrane (\(\gamma\)) of the buccal root of the molar. C. ×3.2.

Fig. 12. The termination of the alveolar-dental branch supplies the gingiva (\(\gamma\)) attached to the external alveolar plate. C. ×3.2.

Fig. 13. Higher power magnification of the root apices in fig. 12. C. ×3.2.

Fig. 14. Spongy substance of the maxillary bone (x). Premolar (\(\triangle\)). C. ×3.2.

Fig. 15. Medial and superior view of the pulpal twig of the canine. Two twigs enter the foramina. C. ×3.0.

Fig. 16. Lateral view of the alveolar-dental branches around the premolars. The branch divides into two, the buccal (\(\gamma\)) and palatal (\(\gamma\)) alveolar-dental ones. C. ×2.6.

Fig. 17. Medial view of the terminal portion. Arterial plexus around the root of the canine (x) and incisors (\(\triangle\)). Greater palatine artery (O). Canine (\(\gamma\)). C. ×1.5.
Plate III

Figs. 18 and 19. Medial view of the terminal portion.

Fig. 18. Both arterial plexus around the root apexes of the canine (x) and incisor (Δ). They communicate with each other (\). C. x 2.3.

Fig. 19. Arterial plexus around the root of incisors (Δ). Arterial capillaries of the periodontal membrane (\). Arteries in the dental pulp (x). C. x 2.3.

Infraorbital artery (figs. 20–28)

Fig. 20. Lateral view of the beginning portion. C. x 3.6.

Fig. 21. Medial view of the beginning portion. The case in which the infraorbital artery arises from the lateral wall (\) of the sphenopalatine artery. C. x 2.6.

Fig. 22. Lateral view of the beginning portion. C. x 6.5.

Fig. 23. Superior view of the right orbital portion. Infraorbital branches (\). Infraorbital foramina (x). C. x 4.2.


Plate IV

Fig. 26. Anterior view of the left orbit. Branch to the inferior oblique muscle (\). C. x 3.2.

Fig. 27. Anterolateral view of the orbit. Arterial capillaries to the mucoperiosteum of the maxillary sinus (x). R. sinus maxillaris of the infraorbital artery (\). Infraorbital branch (Δ). C. x 3.7.

Fig. 28. Lateral view of the terminal portion. Infraorbital branch (Δ). Alveolar twig (→). C. x 2.6.

Sphenopalatine artery (figs. 29–41).

Figs. 29–33. Medial view of the beginning portion.

Fig. 29. An upward arch of the common trunk of the sphenopalatine and descending palatine arteries (x). C. x 3.2.

Fig. 30. The sphenopalatine artery arises from the medial wall (\) of the common trunk of the posterior superior alveolar and infraorbital arteries. C. x 4.2.

Fig. 31. A small canal (\) continues to a foramen (\). Middle concha (x). Inferior concha (x x). R. sinus maxillaris (O). R. nasalis parietalis inferior (Δ). R. conchalis nasalis inferioris (O). C. x 3.2.

Fig. 32. Sphenopalatine foramen (O). Middle concha (x). C. x 3.2.

Fig. 33. Posterior ethmoidal artery (x). C. x 3.2.

Plate V

Fig. 34. Medial view of the beginning portion. Ophthalmic artery (→). C. x 3.2.

Fig. 35. Medial view of the septum. Posterior ethmoidal artery (x). Arterial network (Δ). C. x 3.2.

Figs. 36, 37 and 38. Medial view of the beginning portion.

Fig. 36. Medial (x) and lateral (Δ) branches of the A. conchalis nasalis mediae. Rr. nasales parietales laterales (O). C. x 3.2.

Fig. 37. Middle concha (x). Small canal (\). R. sinus maxillaris (O). C. x 3.2.
Fig. 38. The A. conchalis nasalis mediae arises from the superior wall of the descending palatine artery. C. ×3.2.


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Plate I

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Arteries around the maxillary Sinus in Macacus

Plate III

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Arteries around the Maxillary Sinus in Macacus

Plate V