Microvascular Architecture of the Lingual Papillae in the Japanese Monkey (*Macaca fuscata fuscata*)

By

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— Received for Publication, July 15, 1992 —

Key Words: Microvasculature, lingual papillae, corrosion castings, Japanese monkey

Abstract: The microvascular architecture of all kinds of lingual papillae in the Japanese monkey was investigated on plastic corrosion casts and epithelium-separated specimens under a scanning electron microscope. Three kinds of the filiform papillae were observed; the circularly-arranged papillae with a small papilla in the center on the lingual apex, a simple large conical papilla with a bilateral pair of spines on the lingual body and the aggregated filiform papillae on the top of an epithelial projection on the lingual radix. Five to eight capillary loops were arranged in a circle of the above filiform papillae on the lingual apex. Arterioles ascended in the filiform center on the lingual body to form an intrapapillary network in the shape of a large cone, from which capillary loops were observed only on the top surface of the papilla. Capillary loops arising from the subepithelial capillary network in the epithelial projection were distributed to each filiform papilla on the lingual radix. Globular fungiform papilla on the lingual apex were supplied by capillary loops radiating from the intrapapillary capillary network. Cylindrical fungiform papillae on the lingual body were supplied by capillary loops only on the top surface of each fungiform papilla without any loop formation on the lateral surface. Four vallate papillae, a medial and lateral pair, were supplied by arterioles ascending in the papillary center to form an intrapapillary capillary network, from which capillary loops were sent off on the top surface of the papilla and formed a network in the lateral surface. Each foliate papilla was supplied by an arteriole passing through each papillary center along the long axis and 5 or 6 capillary loops from the arteriole on the frontal section.

Every lingual papilla was supplied by a characteristic microvascular pattern, which correlated closely with the location of the papillae and areas reflecting the regional role of the tongue movement, especially in the filiform and fungiform papillae.

Introduction

Many investigators have been interested in the comparative morphology of the lingual papillae. Sonntag (1920, 1921a,b,c,d,e, 1925) described a series of the comparative anatomy of mammalian tongues. Recently, the minute morphology of the papillae, including the internal structures, has been studied three-dimensionally by scanning electron microscopy. These SEM-studies have generally been made on the rodent tongue, for no particular reason. Only the description of Mitsui (1990) was made on the primate tongue.

The microvasculature in the lingual papillae was investigated under SEM utilizing microcorrosion casts by Kishi (1976) in the dog, Yamashita (1985) in the Japanese mole, Nagato *et al.* (1987) and Kuramae (1989) in the rat and Okada *et al.* (1992) in primates and insectivores. The present authors attempted to obtain detailed findings on the microvascular architecture of the lingual papillae of the

Japanese monkey by means of the plastic micro-corrosion casts and epithelium-separated specimens. Results obtained are discussed with previous findings.

Material and Methods

Eight adult Japanese monkeys (*Macaca fuscata fuscata*) were used for this study. On five of them, acrylic plastic was injected via the common carotid arteries utilizing the plastic injection method (Ohta *et al.*, 1990). Tongues were dissected from the injected materials and treated with 10% sodium hydroxide solution to obtain corrosion casts of the lingual microvasculature. These were coated with gold using an ion sputter coater (JFG-1500, JEOL) and examined under a scanning electron microscope (JSM-T300, JEOL, accelerating voltage 5 kV, working distance 40 mm). In other three monkeys, 2.5% glutaraldehyde was perfused via the common carotid

arteries. The tongue of one animal of them was dissected out, postfixed in 1% osmic acid, embedded in SPURR's resin and ultrathin-sectioned for a transmission electron microscopy (JEM-100S, JEOL). Tongues of the remaining two animals were treated with 2N sodium bromide and freeze-dried by t-butyl alcohol to prepare epithelium-separated specimens.

Findings

1. Microvascular architecture of the lingual papillae

a. General aspect (Figs. 1, 2 and 3)

As there was no submucous tissue on the lingual dorsum, the lamina propria was located immediately superficial to the linguae proper muscles, bordered apparently by the lingual aponeurosis. Arterioles arising from the deep lingual artery ascended, giving off numerous branches to the muscles, up to the lamina propria, after penetrating the aponeurosis and formed an arteriolar network at the same level as the venular network. A few arteriovenous anastomoses were observed in the lingual apical area (Figs. 1 and 2) except for the lingual body and radical areas. From this arteriolar network, capillaries arose toward each papilla, where a capillary loop or characteristic capillary network was formed (Fig. 3). The descending crus flowed into the lamina propria venular network, which also received the subepithelial capillary network in the interpapillary areas.

b. Filiform papillae

The microvasculature of this papilla is described here. Findings obtained on the epithelium-separated specimen have been added to those reported by Okada *et al.* (1992).

1) Lingual apex (Figs. 4 and 5)

Circularly-arranged filiform papillae (Mitsui 1990) composed of 5–8 filiforms were supplied by two or three arterioles, which gave off two to three capillaries. Each filiform papilla was nourished by a spiral capillary loop (40–50 μm in height). The tip of the loop was irregularly thickened (about 10 μm in diameter) and the descending crus from each filiform flowed down to a venule which drained into the lamina propria venular network. A small filiform located in the center of the circularly-arranged filiform papillae was supplied by a single, low hairpin loop (about 20 μm in height) (Fig. 4). Each connective tissue papilla of the filiform papillae on the epithelium-separated specimen appeared a sharp cone, numbering 5–8, similar to those of the capillary loop. These papillae were arranged in a circle (Fig. 5).

2) Lingual body (Figs. 6 and 7)

An arteriole entered the center of the large conical papilla (Mitsui 1990) and formed an intrapapillary capillary network corresponding to the papillary shape by ramifying and anastomosing with adjacent arterioles. This network continued to the subepithelial capillary network in the interpapillary areas (Fig. 6). The top of the intrapapillary capillary network was appeared as high hairpin loops (30–40 μm in height). The descending crus drained into a venule passing in the papillary center and flowed into the lamina propria venular network. On the epithelium-separated specimen, holes corresponding to the connective tissue papillae were polygonal in shape and separated from each other. Fine wrinkles observed between the holes were imprints of meshes of the subepithelial network in the interpapillary area (Fig. 7). Neither connective tissue papillae nor capillary architecture was observed in the spine (Mitsui 1990) positioned bilateral to each filiform papilla (Fig. 6).

3) Lingual radix

One or two arterioles were directed to an epithelial projection, on which the small aggregated filiform papillae (Mitsui 1990) were located, and formed a capillary network by ramifying and anastomosing with each other. This network gave rise to single hairpin loops (about 30 μm in height), each of which supplied each of the aggregated filiform papillae. Blood from the capillary loops and network flowed down in to the lamina propria venular network.

c. Fungiform papillae

1) Lingual apex (Fig. 4)

One or two arterioles radiated into capillaries toward the periphery of the globular fungiform papilla. Each capillary formed a loop (50–60 μm in height). These were arranged in a regular radiate line along a globular surface of the fungiform papilla toward the connective tissue (secondary) papillae without anastomosing (Fig. 4). Blood of the loops flowed into venous capillaries in the papillary center and descended toward the lamina propria venular network.

2) Lingual body (Fig. 6)

An arteriole passed upward in the papilla, ramifying several times, and formed a cylindrical capillary network in the papillary center. On the lateral surface of the papilla, the secondary papillae were underdeveloped, but high capillary loops (80–100 μm in height) were formed on the top surface, where the secondary papillae were well developed. Blood from these capillaries drained into the lamina propria

venular network via venules in the papillary center.

d. Vallate papillae (Figs. 8 and 9)

Two or three arterioles ramified immediately after entering the papilla and formed a capillary network on the lateral surface of the papilla, where the secondary papillae were underdeveloped. Hairpin loops (20–30 μm in height) were formed on the top surface, where the secondary papillae were well developed (Figs. 8 and 9). The capillary loops anastomosed with adjacent ones in the secondary papillae and drained into two or three venules in the papillary center and flowed into the lamina propria venular network. Capillary loops (about 20 μm in height) supplying the papillary vallum of the lateral pair of the vallate papillae formed double or triple rows (Fig. 8). The papillary vallum of the median pair of the vallate papillae was not typical in form, and capillary loops were difficult to separate from those in the surrounding subepithelial capillary network, since they were rather continuous with each other. A capillary network was formed in the lamina propria opposite to the papillary sulcus of the vallate (Fig. 9).

e. Foliate papillae (Figs. 10 and 11)

An arteriole supplying each papillary lobe passed along its longitudinal axis and gave rise to radiating capillaries in the papilla (Figs. 10 and 11). They ramified to form high capillary loops (30–40 μm in height) on the top surface of the foliate, where the secondary papillae were well developed. These loops were arranged in fairly regular rows on the frontal section, numbering 5–6 in each lobe (Fig. 11). A capillary network spread on the lateral side of the foliate, where the secondary papillae were underdeveloped. Since anterior lobes became lower and the secondary papillae on the top surface diminished in size and number, the capillary network also became flattened and transferred to the subepithelial capillary network. Capillaries in the secondary papillae anastomosed with each other and drained into venules running parallel to the longitudinal axis of the lobe.

2. TEM structures of the blood capillary wall in the lingual papillae (Fig. 15)

The nucleus of endothelial cell was flat and located on the opposite side of the epithelial layer. The cytoplasm of the epithelial side was always thin with many fenestrations. On the opposite side, microvilli-like structures and marginal folds protruded into the lumen with many pinocytotic vesicles. Continuous basement membrane was observed surrounding the capillary wall and pericytes.

Discussion

Scanning electron microscopy on corrosion casts of the microvasculature of the mammalian tongue has been performed by Kishi *et al.* in man (1975), and the dog (1976), by Yamashita in the Japanese mole (1985), Nagato *et al.* in the rat (1987), Kuramae in the rat (1989) and Okada *et al.* in some primates and insectivores (1992). We attempted to study the microvascular architecture of all kinds of the lingual papillae in the Japanese monkey on SEM, based on the fine structure of the papillae reported by Mitsui (1990). We examined the results on functional morphology from the viewpoint of comparative angiology.

Previously, Okano (1960) studied the arteriolar and venular networks in the lamina propria of the lingual dorsum in the dog and cat by light microscopic examination of acrylic casts. Kuramae (1989), however, reported that the arterioles did not form a meshwork in the lamina propria of the rat; only a venular network was observed. In the Japanese monkey, both types of dense networks were found, as also elucidated in the dog and cat (Okano 1960). Such networks may be significant in blood stream control for complicated tongue movements. Kishi *et al.* (1976, 1988) suggested that the distribution of arteriovenous anastomoses in the lamina propria of the dog lingual dorsum may be suitable for the control of blood temperature. The distribution of arteriovenous anastomoses in the Japanese monkey was not dense on the lingual dorsum except at its apex.

a. Filiform papillae

The present authors agree with the description of locational differences on the lingual dorsum in the morphology of the filiform papillae reported by Okada *et al.* (1992). Meshworks of the capillary network in the anterior and posterior surfaces of the filiform papilla do not show any locational differences, although the thickness of the cornified layer differs on the two surfaces. It was confirmed that there were no capillary elements in the spines of the filiform papilla (Mitsui 1990), only in the epithelial processes. The capillary loops usually were larger in diameter in the lingual apical area than in the radical area; they showed a spiral passage and swollen loop tip with irregular diameters. We have considered that this peculiar feature of the capillaries accommodates itself to the violent and complicated movements of the lingual apex. In other words, these capillaries may be able to expand and constrict freely according to external pressures. The present study revealed locational differences in the microvascular architecture, as indicated by Mitsui (1990), on the fine morphology of the filiform papillae of the Japanese monkey.

b. Fungiform papillae

As in the filiform papilla, the microvascular pattern was entirely due to the form of the papilla. These differences correlate to locational differences such as in the lingual apical and body areas. Especially in the globular fungiform papilla of the lingual apex, the vascular pattern is arranged in splendid regularity, that is, capillary loops of similar heights radiate in all directions along the globular surface of the papilla. This arrangement may be an adequate accommodation to severe rubbing motions against various external forces such as food and mastication. However, the vascular pattern of the fungiform papilla of the lingual body area is similar to that of the filiform papilla, that is, the well-developed capillary loops exist only in its top surface. Only the top area is influenced by the external forces mentioned above. No differences were found between areas with taste buds and other areas.

c. Vallate papillae

The vascular pattern in the vallate papilla may be represented as an enlargement of that in the fungiform papilla of the lingual body area. It is also similar to that in man (Kishi *et al.*, 1975) and the dog (Kishi *et al.*, 1976), but quite different from that in Japanese mole (Yamashita 1985), in which circular capillary loops are seen. In the papillary vallum, the capillary loop appears a simple hairpin, similar to that in man, but different from that in the dog and Japanese mole, in which it appears a basket shape. Meshwork patterns are not influenced by the presence of the taste buds. The construction and arrangement of the network in the superior view of the corrosion cast do not show the splendid regular radiation seen in the fungiform papilla, but is enlarged in all directions.

d. Foliate papillae

The microvasculature in the foliate papilla is arranged in the shape of a long cylinder in man, as reported by Kishi *et al.* (1975). In the present paper, a detailed meshwork or capillary loops were demonstrated as follows: Since the secondary papillae are well developed on the top surface of the foliate papilla of the Japanese monkey, five or six rows of capillary loops are impressively arranged in each foliate. This difference between the Japanese monkey and man is apparently due to the developmental extent of the foliate papilla itself. In addition, each of the foliate papilla in the Japanese monkey is much narrower, but higher than that in man. Development of the vascular architecture is more distinct and characteristic on the top surface; there are no capillary loops on the lateral surface facing the interfoliate grooves.

In conclusion, locational differences in the microvasculature of the filiform papillae may depend on forms adapted to acquired habits, although the basic form of the filiform papillae is aggregated in primates. Blood capillaries in the fungiform, vallate and foliate papillae always develop to a loop formation on the top surface, where the secondary papillae are well developed. Only the capillary network extends in a plane without any loop formation on the lateral surface facing the interpapillary groove. There are no correlations between the existence of taste buds and capillary meshworks.

Acknowledgements

The authors wish to express their sincere gratitude to Professor Yoshikuni Ohta for critically reading this manuscript, and to all the staff members of the Department of Anatomy for their invaluable assistance.

This work was presented at the 32nd Annual Meeting of the Japanese Association for Oral Biology in Chiba on 21 October 1990.

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Explanation of Figures

Plate I

Fig. 1. General view of the filiform and fungiform papillae on a sagittal section of the lingual apex.

Arterioles arising from the deep lingual artery, giving off twigs to the linguae proper muscles, penetrate the lingual aponeurosis (dotted line) up to the lamina propria, where they form an arteriolar network. Capillaries leave this network toward the fungiform (Fu) and filiform (Fi) papillae. Detail of these papillae is shown in Fig. 4. Bar = 1 mm

Fig. 2. Lamina propria vascular network viewed from the side of the aponeurosis.

Arterioles arising from the deep lingual artery form an arteriolar network (A) at the same level as the lamina propria venular network (V). Bar = 700 μ m

Fig. 3. Microvascular cast of the whole lingual dorsum.

The filiform papillae are observed all over the lingual dorsum, the fungiform papillae (Fu) mainly on the lingual apex, four vallate papillae (V) (two medial and two lateral pairs) on the lingual radix and the foliate papilla (Fo) on the posterior lateral borders of the lingual body.

Plate II

Fig. 4. Filiform and fungiform papillae on the lingual apex.

Five to eight simple hairpin capillary loops are observed in each of the circularly-arranged filiform papillae (Fi), and each of the loops supplies each papilla. Globular fungiform papilla (Fu) is supplied by capillary loops radiating in several rows.
Bar = 100 μ m

Fig. 5. Circularly-arranged filiform on an epithelium-separated specimen.

Connective tissue papillae of the lamina propria are also arranged in a circle. Bar = 50 μ m

Plate III

Fig. 6. Filiform and fungiform papillae on the lingual body.

The filiform papilla (Fi) is supplied by a large conical capillary network. Capillary loops on the top surface are clearly observed in both filiform and fungiform papillae (Fu). Bar = 80 μ m

Fig. 7. Epithelial side of an epithelium-separated specimen.

Many polygonal holes are formed by the filiform papillae. Fine wrinkles (arrows) between the holes are imprinted by the subepithelial capillary network. Bilateral spines (arrowheads) of each filiform papilla do not have connective tissue papillae. Bar = 150 μ m

Plate IV

Fig. 8. Superior view of a vallate papilla. Bar = 200 μ m

Fig. 9. A sagittal section of a vallate papilla. Bar = 200 μ m

Capillary loops are formed on the top of the papilla. Capillary networks are observed in the lateral wall of the papillary vallum in two or three rows (arrowheads). Two or three arterioles (A) enter a papilla and ramify toward the vallum to form a capillary network in a plane near its bottom.

Plate V

Fig. 10. Superior view of the foliate papillae.

This photograph was taken from the lingual border in a horizontal plane. On the top surface of the foliate lobe, high capillary loops are arranged regularly in several rows on frontal sections. Bar = 100 μ m

Fig. 11. A section tangential to the lingual dorsum through the foliate papillae.

Arterioles (A) supplying each foliate pass along the long axis of the papillary lobe in each papillary base. On the lateral surface of the foliate lobe, a capillary network is formed in a plane, but capillary loops are seen only in the top surface. V: venule
Bar = 80 μ m

Fig. 12. TEM photograph of a blood capillary of the filiform papilla.

Nucleus of the endothelial cell (E) is located on the opposite side of the epithelium (Ep). Cytoplasm of the epithelial side is not thick with fenestrations. Bar = 2 μ m