Gross Anatomical Classification of the Courses of the Human Sublingual Artery

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MINI-ABSTRACT

Courses of the sublingual artery were divided into three categories: those passing medial or lateral to the hyoglossus and that piercing the mylohyoid, which were subdivided into five types.

Abstract

The purpose of the present study was to classify the courses of the human sublingual artery. For this purpose, the arteries supplying the floor of the mouth and the tongue were gross anatomically investigated, using 101 sides of 53 cadavers. The courses were divided into three categories: those passing medial or lateral to the hyoglossus (Categories M and L) and that piercing the mylohyoid (Category P), which were subdivided into five types. Category M had one type regarded as the usual type in which the lingual artery took the usual pattern of distribution. Categories L and P, in which the sublingual artery arose from the facial or submental artery, had the respective two types and were collectively regarded as the unusual type. Sixty-one and 36 of the 101 sides were of the usual and unusual types, respectively, the latter of which included 17 of Category L and 19 of Category P. The remaining four were variations of the lingual artery itself. On examining the types by gender, the usual type was more often found in females (75.6%), whereas the unusual type was more often found in males (48.1%). Bilateral occurrence of the same type was often found in both the usual type (77.4%) and the unusual type (65.0%). Existence of the sublingual artery branch significantly increased the thicknesses of the submental arteries.

The classification proposed here will conceivably contribute to safer dental implant surgery and more accurate interpretation of angiographic images of arteries in the floor of the mouth.

Key words: gross anatomy, human, lingual artery, sublingual artery, submental artery

Introduction

Arteries distributed in the floor of the mouth, particularly the sublingual artery, has attracted growing interest among dentists, because vascular injury to the floor of the mouth, associated with the placement of dental implants, has become a serious problem with the spread of dental implant surgery (Flanagan 2003, Kalpidis and Setayesh 2004, Jo et al. 2011). Several gross anatomical studies were recently conducted on the courses of the sublingual artery (Loukas et al. 2008, Rosano et al. 2009, Fujita et al. 2012, Katsumi et al. 2013), but those studies were confined to the peripheral distribution of the artery and its point of entrance into the anterior mandible. Although they focus on the relationship to vascular injury associated with dental implant surgery, they do not necessarily provide a comprehensive picture of the entire course of the artery. On the other hand, it is well known that when the usual sublingual artery arising from the lingual artery is absent, it is replaced with a branch which arises from the distal portion of the submental artery (a branch of the facial artery) and then passes upwards to pierce the mylohyoid and finally reach the sublingual region (Tachihara 1958, Bavitz et al. 1994, Hofschneider et al. 1999, Loukas et al. 2008, Katsumi et al. 2013, Fujita et al. 2012). But there are no studies comprehensively investigating the case of absence of the sublingual artery.

Classification of courses of the sublingual artery, including the artery replacing it in its absence, is the purpose of the present study, in which the whole distribution of those arteries including their parent arteries were gross anatomically examined.

The classification of the course of the artery will not only clarify the anatomical facts that should be paid attention to for prevention of vascular injury during dental implant surgery, but also provide information necessary to interpret angiographic images of vessels in and around the floor of the mouth or to determine the ligation site of vessel when arresting bleeding in the floor of the mouth.

Materials and methods

The present study used 101 body sides of 53 Japanese cadavers (28 males and 25 females) for dissection practices at the Tokushima University School of Dentistry and School of Medicine. Of the 101 body sides, 54 sides were male and 47 sides were female, and 49 sides were right and 52 sides were left. In all 101 sides, the whole distribution of the lingual artery including the deep lingual and the sublingual arteries, the portion of the facial artery from the origin site to the base of mandible, and the full length of the submental artery were gross anatomically traced. In 39 body sides of 21 cadavers, the anatomical structures throughout the sublingual surface of the tongue to the sublingual region were first exposed from front without removing the mandible, with special regard to blood vessels, nerves, sublingual gland, submandibular duct, and mylohyoid and hyoglossus muscles. The submental artery was then exposed in the submandibular region. In the remaining 62 body sides of 32 cadavers, the submental artery was first exposed and only the mandible was removed. The mylohyoid was then brought down laterally and the anatomical structures throughout the sublingual surface of the tongue to the sublingual region were then exposed from outside with special regard to the same structures as those described above.

In 53 body sides of 30 cadavers, the comprehensive investigation on position and thickness of major branching sites of blood vessels was additionally performed throughout the courses of the lingual artery, the proximal portion of the facial artery, and the submental artery, using a slide caliper. Items used finally in the present study are as follows. First, thicknesses of the beginning sites of each of the lingual, facial, and submental arteries were analyzed to examine the effects of the existence of a sublingual artery branch on the thicknesses of the arteries. The t-test was adopted for the examination of significant difference, and P-values less than 0.05 were regarded as significant difference. Second, in the event that the unusual sublingual artery arose from the facial artery, the thicknesses of the two arteries and the submental artery, and also interval between the arising site of the submental artery and that of the unusual sublingual artery were measured to explain the appearance of the unusual sublingual artery. While in the event of the unusual sublingual artery arising from the submental artery, the thicknesses of the submental artery before and after the arising site and the unusual sublingual artery were measured for the same purpose. As for in the cases of the unusual sublingual artery, the same items of the measurement were selectively performed in the bodies excluded from the comprehensive investigation to extend the measurement to all cases.

Results

1. Various types of course of the sublingual artery and their ratios of occurrence (Figs. 1 to 3 and Table 1)

The courses of the sublingual artery were largely classified into three categories, which we called Categories M, L and P.

1) Category M (Figs. 1 and 4)

We defined it as one in which the lingual artery giving rise to the sublingual artery or the sublingual artery proper passed medial to the hyoglossus. In this category, we could find only one type of course, Type M-1, in which the lingual artery took the ordinary distribution as described in general textbooks. This type was found in 61 of 101 body sides (27 males and 34 females; 33 lefts and 28 rights). In this type, the lingual artery entered medial to the posterior border of the hyoglossus just above the greater horn of the hyoid bone and ran forward under cover of that muscle to finally divide into the deep lingual and the sublingual arteries near the anterior border of that muscle. The deep lingual artery passed toward the tip of the tongue between the inferior longitudinal muscle and the genioglossus, while the sublingual artery ran forward along the inferior margin of the sublingual gland just above the mylohyoid to reach a point near the mental spines.

2) Category L (Fig. 2)

We defined it as one in which the sublingual artery wholly passed lateral to the hyoglossus. Category L occurred in 17 of 101 sides. In this category, the sublingual artery arose from the facial artery at a site less than 10 mm (along the artery) proximal to the origin of the submental artery (12 sides) or from the beginning portion of the submental artery (five sides). The thickness of the sublingual artery is 1.2 to 2.4 mm, being almost always the same or a little larger than the submental artery. Immediately after arising, the sublingual artery entered the floor of the mouth after crossing the posterior border of the mylohyoid to pass forward above the mylohyoid and lateral to the hyoglossus (Fig. 5). In the region anterior to the hyoglossus, it followed the same course as in Type M-1. The lingual artery took the same route as in Type M-1 before reaching the anterior border of the hyoglossus. But it then passed toward the tip of the tongue solely as the deep lingual artery without giving rise to the sublingual artery. Accordingly the deep lingual artery and the sublingual artery took routes separated from each other by the hyoglossus (Fig. 6).

We found two types of course in Category L, Types L-1 and L-2, depending on the relation between the sublingual artery and the deep lingual artery (Fig. 2). Type L-1 had no communication between the sublingual artery and the deep lingual artery and consequently the two arteries took routes wholly separate from each other. We found 16 sides of Type L-1 (10 males and six females; five lefts and eleven rights) among 17 sides of Category L. In Type L-2, however, communication between the two arteries was found in the sublingual region. We found only one side of this type (male, left).

3) Category P (Fig. 3)

We defined it as one in which the sublingual artery arose from the submental artery at a site far distal to the arising site in Category L, and after passing a short distance it pierced the mylohyoid to enter the sublingual region (Fig. 7). Most of the piercing sites were located at the middle one-third of the mylohyoid divided into three equal parts in parallel with the direction of its muscle bundles. The sublingual artery then followed the same course as in Type M-1. Category P occurred in 19 of 101 sides.

The thickness of the sublingual artery was 1.2 to 2.2 mm. Comparing its thickness with that of the submental artery after giving rise to the sublingual artery, 12 of 19 sides (63.2%) had the sublingual artery thicker than the submental artery, so that in the cases of Category P, the submental artery more often exhibited the appearance that it continued to the sublingual artery and then pierced the mylohyoid to supply the sublingual region.

We found two types of course in this category, Types P-1 and P-2, depending on the relation to the deep lingual artery. Type P-1 (Fig. 3) was a type in which the deep lingual artery continuing from the original lingual artery was wholly separated from the sublingual artery piercing the mylohyoid (Fig. 7), and was seen in 17 (twelve males and five females; eleven lefts and six rights) among 19 sides of Category P. In Type P-2 (Fig. 3), seen in two (two males; one left and one right) among 19 sides, communication between the two arteries was found in the sublingual region (Fig. 8).

4) Variations of the lingual artery itself

In four of 101 sides (two males and two females; one left and three rights), we found that an artery taking the same route as the sublingual artery of Category L or P divided into the deep lingual artery and the sublingual artery in the sublingual region. The artery therefore took on an appearance analogous to the lingual artery, provided that a remnant of the lingual artery arose from the same site as in the original lingual artery and entered medial to the hyoglossus just above the greater horn of the hyoid bone to be distributed in the root of the tongue. Hereafter we called it variant lingual artery.

2. Ratios of occurrence of usual and unusual types of sublingual artery course, and their difference between male and female as well as between left and right sides (Tables 1 and 2)

We regarded Type M-1 as the usual type, because it was the distribution pattern of the lingual artery described in general textbooks and displayed the highest ratio of occurrence among the different types of course. Accordingly, the types of course other than Type M-1 were collectively included in the unusual type (Table 1). We found the usual type in 61 of 101 body sides (60.4%) and the unusual type in the 36 sides (35.6%). The remaining four sides (4.0%) were regarded as the variation of the lingual artery itself, and therefore excluded from accounting the classification of the course of sublingual artery.

In 63 of 101 sides in which the external carotid artery remained intact, ratio of occurrence of the unusual type was compared between the case (20 sides) in which the lingual and facial arteries arose together from the external carotid artery as a common trunk and the case (43 sides) in which the two arteries separately arose from that artery. The ratios were eight of 20 sides (40%) in the case of common trunk formation and 21 of 43 sides (48.8%) in the case of separate arising, showing slightly higher ratio in the latter case.

On examining 97 sides excluding four sides of the variant lingual artery by gender (Table 2), the usual and unusual types were found in 27 and 25, respectively, of 52 sides of male. In females, however, they were found in 34 and 11, respectively, of 45 sides. Accordingly, the usual type (the ratio 75.6%) was found far more often than the unusual type in females, whereas in male, the unusual type (the ratio 48.1%) was found in the almost same ratio as the usual type.

On examining the 97 sides by laterality (Table 2), the usual and unusual types were occurred in 33 and 18, respectively, of 51 left sides. In 46 right sides, however, they occurred in 28 and 18, respectively. Accordingly, the ratios of occurrence of the unusual type were 35.3% and 39.1% in left and right sides, respectively, showing slightly higher ratio in the right.

3. Ratios of bilateral occurrence of the usual or unusual type (Table 2)

We could obtain findings from both the left and right sides in 44 cadavers (24 males and 20 females) excluding four cadavers having the variant lingual artery. Twenty-four cadavers (10 males and 14 females) had the usual type on the both sides, and seven cadavers (six males and one females) had the usual type only on either side. In the remaining 13 cadavers (eight males and five females), however, the unusual type was found on both the left and right sides. In eight cadavers (four males and four females) of them, even the exact type of course (e.g., L-1, P-2, and L-3) coincided with each other on both sides, but in five cadavers (four males, one female), the type of course did not coincide. It was clarified from the above findings that ratio of bilateral occurrence was high not only in the usual type (24 of 31 cadavers, 77.4%) but also in the unusual type (13 of 20 cadavers, 65.0%), and also suggested that when the usual or unusual type was found on one side, the same type was also found on the other side in many cases, in more than half of which even the exact type of course (e.g., L-1, P-2, and L-3) coincided with each other.

In four cadavers having the variant lingual artery, two male and two female cadavers had the usual and unusual types of the sublingual artery, respectively, on the opposite side, suggesting that the unusual type might coincide rarely with the contralateral variant lingual artery.

4. Effects of the existence of the sublingual artery as a branch on thickness of blood vessel (Table 3)

The effects were examined in the lingual, facial, and submental arteries, in 53 sides excluding cases of the variant lingual artery, in which 28 sides of Category M, 12 sides of Category L, and 13 sides of Category L were included. It was consequently clarified that the existence of the sublingual artery as a branch significantly increased only the thicknesses of the submental arteries. Describing in detail, the thickness of the unusual submental artery having the sublingual artery (2.11 ± 0.40 mm) was significantly larger than that of the usual artery not having it (1.54 ± 0.30 mm). In the lingual artery, no significant difference was seen, although the thickness of the usual artery having the sublingual artery (2.53 ± 0.30 mm) tended to be larger than that of the unusual artery not having the sublingual artery (2.38 ± 0.34mm). The similar tendency was also seen in the facial artery; the thickness of the unusual artery having the sublingual artery was 2.68 ± 0.18mm, while that of the usual artery not having the sublingual artery was 2.56 ± 0.36mm.

Discussion

1. Classification of the courses of the sublingual artery

The present study largely classified the course into three categories: the course medial to the hyoglossus, that lateral to it, and that piercing the mylohyoid, which were further subdivided into a total of five types of courses depending on the relation between the sublingual artery and the deep lingual artery (Figs. 1 to 3). To date there are no studies on the systematic classification of the courses of the sublingual artery.

Cases in which the sublingual artery did not arise from the usual lingual artery were previously regarded as “absence of the sublingual artery”. On applying the present classification to this concept, Type L-1, Type P-1 and the variant lingual arteries correspond to “the absence”, and consequently the ratio of occurrence of the absence was 37 of 101 sides examined (36.6%) with 17 of 52 sides (32.7%) on the left and 20 of 49 sides (40.8%) on the right. In past studies, the ratio of absence was reported to be 43.0% on the left and 56.2% on the right (Tachihara 1958), 31.4% (Katsumi et al. 2013) and 45% (Fujita et al. 2012) in Japanese, while 29.4% (Hofschneider et al. 1999) and 27% (Loukas et al. 2008) were reported in non-Japanese, suggesting the tendency of higher ratio in Japanese.

1) The course medial to the hyoglossus

Only one type of course (Type M-1) was seen in this category. This is the usual type described in general textbooks. Its ratio of occurrence was 60.4% in the present study, with 63% (Katsumi et al. 2013) or 46% (Fujita et al. 2012) reported in other studies on Japanese, and 58.3% (Hofschneider et al. 1999) in non-Japanese. These values appear to be quite low considering that they are the ratios of occurrence of artery taking ordinary course as described in general textbooks.

2) The course lateral to the hyoglossus

As regards this category of the course, only two studies using Japanese cadavers, the present one and Katsumi et al. (2013), were seen among available past studies. The ratio of occurrence was 16.8% in the present study. Katsumi et al. (2013) reported a ratio of occurrence of 9.2% for a course similar to Type

L-1, in which the submental artery divided into two large branches, one taking the ordinary route of the submental artery and the other passing forward above the mylohyoid to reach the submental region. However, they do not describe a lateral course arising from the facial artery as observed in the present study.

3) The course piercing the mylohyoid

The ratio of occurrence for this course was 18.8% in the present study. The ratio was reported to be 20.2% (cited in Tachihara 1958), 26.0% (Katsumi et al. 2013), or 45.0% (Fujita et al. 2012) in Japanese, while 41.2% (Hofschneider et al. 1999) or 59.7% (Bavitz et al. 1994) were reported in non-Japanese, suggesting the tendency of lower ratio in Japanese. Though no study mentions any classification of this type, it is inferred from the description by Katsumi et al. (2013) that they observed Type P-1 and Type P-2 in the ratios of 20.4% and 5.6%, respectively.

In animals, the sublingual artery of the rat is known to take the medial course similar to Type M-1 of the human (Shimizu 1986), while in the dog (Irifune 1980) and the cat (Hikida and Suwa 1989), the sublingual artery takes the piercing course, in which the artery pierces the mylohyoid as a branch of the submental artery to reach the sublingual region.

2. Anatomical implication of the variable courses of the sublingual artery

Fig. 9 is a diagrammatic drawing comprehensively showing all possible routes that enable the sublingual artery and its relevant arteries to reach their destinations, based on the findings obtained in the present study. Each type of course of the sublingual artery in Figs. 1 to 3 is drawn on the basis of this drawing, so that it is easily understood which routes have been traced to accomplish each type of course. Arteries drawn in bold lines, the proximal portions of the facial and lingual arteries, and the submental artery are stable vessels having few variations. The area supplied by the lingual artery is known to be divided into three vascular territories independent of each other: the body of the tongue supplied by the distal portion of the lingual artery and the deep lingual artery, the sublingual region supplied by the sublingual artery, and the root of the tongue supplied by the dorsal lingual arteries arising from the proximal portion of the lingual artery (Lopez et al. 2007). The present study clarified that the arteries responsible for those vascular territories showed variability different from each other.

The finding that the proximal portion of the lingual artery continuing to the dorsal lingual arteries as well as the submental artery takes a stable course having few variations may be related to the fact that they are vessels sending blood to the base portion of the floor of the mouth from which the mobile body of the tongue grows. In the variant lingual artery, however, the deep lingual artery did not continue from the proximal portion of the lingual artery but from the sublingual artery of Category L or P, with the proximal portion of the lingual artery ending as the dorsal lingual arteries. This finding shows that variations are also seen in the distal portion of the lingual artery and the deep lingual artery supplying the body of the tongue, and also suggests the possibility that the body of the tongue can receive arterial supply solely from the arteries supplying the base portion of the floor of the mouth other than the root of the tongue, although its ratio of occurrence is low. On the other hand, the high variability of the sublingual artery may reflect the positional characteristics of the sublingual region with its location between two regions, the body of the tongue and the base portion of the floor of the mouth, making it possible to receive arterial supply from both regions. The description by Kalpidis and Setayesh (2004) that none of the studies was able to identify a sublingual vessel penetrating the mylohyoid muscle into the submandibular region also conceivably suggests the priority of the submental artery to the sublingual artery.

3. Sexual difference and laterality of ratios of occurrence of the usual (Type M-1) and unusual types (Types other than M-1), ratio of bilateral occurrence of each of the types, and thicknesses of the relevant arteries

The present study found a distinct sexual difference, such that the usual type was more frequently found in females, whereas the unusual type was more frequently found in males (Table 2). Though cases examined were a few in number (12 in male, 22 in female), Hofschneider et al. (1999) also reported on the sexual difference that the usual case was more frequently found in females (63.6%) than in males (50.0%). As regards laterality, however, the present study showed that the unusual type was a little more often seen in the right (Table 2). Tachihara (1958) also stated that the sublingual artery arising from the lingual artery was more often absent in the right (56.2%) than in the left (43.0%).

The present study further clarified that the high ratio of bilateral occurrence was found not only in the usual type but also in the unusual type (Table 2). Hofschneider et al. (1999) also reported that bilateral occurrence was found in 70.6% of the total number of the usual and unusual cases.

As regards the thickness of the arteries, the present study showed that the existence of the lingual artery as a branch significantly increased the thickness of the submental artery (Table 3). However, Katsumi et al. (2013) described that not only the submental artery but also the lingual artery significantly increased in thickness. Beside that, the submental artery in the cases of Category P, as shown in the present study, tended to exhibit the appearance that after sending a branch to the submental region, it pierced the mylohyoid to supply the sublingual region.

As described above, the sexual difference, the high ratio of bilateral occurrence, and the thicknesses of the submental artery and possibly the lingual artery provide useful information for predicting the existence of variant sublingual artery.

4. Clinical implications of the high variability of the sublingual artery

1) From the perspective of dental implant surgery

It is very important in dental implant surgery to anatomically determine the peripheral distribution of the sublingual artery and its anastomotic relationships to the submental artery (Loukas et al. 2008, Rosano et al. 2009, Katsumi et al. 2013, Fujita et al. 2012). The reasons for this are as follows: first, serious bleeding complications frequently occur in the anterior mandible during dental implant surgery (Kalpidis and Setayesh 2004); second, in edentulous patients, implant placement in the anterior mandible has been routinely performed for stability and maintenance of complete denture (Jo et al. 2011); and third, the peripheral distribution of the sublingual artery is confined to a region immediately lingual to the anterior mandible (Lopez et al. 2007). Anatomical research on the accessory anterior lingual mandibular foramina, which are the entrance to the mandible for the terminal twigs of the sublingual artery, has also been conducted from these points of view (Kalpidis and Setayesh 2004).

In the posterior mandible, however, the mylohyoid artery instead of the sublingual artery is mentioned as a difficult artery to manage in the event it is severed during dental implant surgery (Flanagan 2003), because the lingual artery, from which the sublingual artery arises, passes medial to the hyoglossus and consequently takes a route a little apart from the mandible. But in the present study, it was clarified that there were a considerable number of cases in which the sublingual artery passed lateral to the hyoglossus to reach its destination and consequently took a route adjacent to the mandible, and also that even the lingual artery itself rarely took this route (the variant lingual artery). These findings suggest that severed hemorrhage associated with dental implant surgery can be incurred not only in the anterior mandible but also in the posterior mandible (Kalpidis and Setayesh 2004).

2) From the perspective of arterial ligation for control of hemorrhage in the sublingual region

Although extraoral ligation of the lingual artery is rarely ever done, it may have to be used to stem uncontrolled bleeding in the sublingual region (Homze et al. 1997; Flanagan 2003; Kalpidis and Setayesh 2004). As clarified in the present study, however, the supply of blood to this region was variable, and the unusual supply direct from the facial artery or by way of the submental artery from the facial artery was seen in many cases. Accordingly, ligation of the facial artery or the submental artery should also be taken into consideration when ligating the lingual artery. Consequently even the description that the submental or facial artery should be ligated first, and then the lingual artery ligated if bleeding is not arrested appears in the literature (Flanagan 2003).

3) From the perspective of understanding angiographic images

Considering the high variability of blood supply to the sublingual region, preoperative understanding of vessel courses in the floor of the mouth is most important for determining the proper site of ligation when arresting bleeding and for determining the proper position of the tip of catheter when selectively injecting anticancer drug or contrast medium into a confined region. Angiography is the most effective technique for preoperative understanding of vessel courses. Additionally, from a preventive viewpoint against hemorrhagic incident, it is anticipated that the importance of angiography before dental implant surgery will be raised in future. For interpretation of angiographic images of the floor of the mouth, however, a comprehensive knowledge of blood supply to this area is indispensable. The classification of courses of the sublingual artery shown in the present study is expected to serve as a basis for interpreting angiographic images of the floor of the mouth.

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Conflict of interest

None.

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Figure legends

Fig. 1 Diagrammatic drawing to show patterns of course of the sublingual artery as well as in Figs. 2 and 3. Dark bold line is the sublingual artery, and pale bold lines are arteries relevant to it. Broken line is a portion of artery covered with the hyoglossus. See Fig. 9 about fine lines. The patterns are largely divided into three Categories: M, L and P, which are further subdivided into a total of five Types. Category M in which the lingual artery (L) giving rise to the sublingual artery (SL) or the sublingual artery proper passes medial to the hyoglossus (HG) is shown here. Only one type of course, Type M-1, was found, in which the lingual artery (L) had an ordinary distribution described in general textbooks. *CC* common carotid artery, *DL* deep lingual artery, *DoL* dorsal lingual arteries, *EC* external carotid artery, *F* facial artery, *HG* hyoglossus muscle, *IC* internal carotid artery, *L* lingual artery, *MH* mylohyoid muscle, *SL* sublingual artery, *SM* submental artery

Fig. 2 Two types of course included in Category L are shown. Category L is characterized by the fact that the sublingual artery (SL) passes lateral to the hyoglossus (HG).

Fig. 3 Two types of course included in Category P are shown. Category P is characterized by the fact that the sublingual artery (SL) pierces the mylohyoid (MH) to reach the sublingual region.

Fig. 4 The course of Type M-1 is viewed from left-laterally after removing the mandible (M) and then turning the mylohyoid (MH) downward. The lingual artery (L) after passing medial to the hyoglossus (HG) is divided into the deep lingual (DL) and the sublingual arteries (SL). *DL* deep lingual artery, *EC* external carotid artery, *F* facial artery, *GG* genioglossus muscle, *GH* geniohyoid muscle, *HG* hyoglossus muscle, *HN* hypoglossal nerve, *L* lingual artery, *LN* lingual nerve, *M* mandible, *MH* mylohyoid muscle, *SG* styloglossus muscle, *SL* sublingual artery, *SLG* sublingual gland, *SM* submental artery, *SMG* submandibular gland, *T* tongue

Fig. 5 The course of Category L is viewed from right-laterally after the same procedures as in Fig. 4.

The deep lingual artery (DL) continues from the lingual artery (L) passing medial to the hyoglossus (HG). But the sublingual artery (SL) passes lateral to HG to reach the lingual surface of the mandible (M). Here, SL has been cut at the arising site and held upward to show the full length of the artery. The filled star mark shows its cut end. In this case, arising site, marked with a filled circle, is located on the facial artery (F) a little proximal to the origin of the submental artery (SM). After arising, SL crosses the posterior border of the mylohyoid (MH) and enters the floor of the mouth to pass lateral to HG. *DL* deep lingual artery, *F* facial artery, *HG* hyoglossus muscle, *HN* hypoglossal nerve, *L* lingual artery, *LN* lingual nerve, *M* mandible, *MH* mylohyoid muscle, *SL* sublingual artery, *SLD* sublingual duct, *SLG* sublingual gland, *SM* submental artery, *SMD* submandibular duct, *SMG* submandibular gland, *T* tongue, *V* vein

Fig. 6 The course of Category L is viewed from front in the oral cavity. The space between the tongue (T) and the mandible (M) are forced open in the right half of the head. It is well understood that the deep lingual artery (DL) and the sublingual artery (SL) take routes completely separated from each other by the hyoglossus (HG) as described in Fig. 5. This case is of Type L-1, because no communication is found between the two arteries. Although not shown in the figure, SL of this case arose from the beginning site of the submental artery. *DL* deep lingual artery, *GG* genioglossus muscle, *GH* geniohyoid muscle, *HG* hyoglossus muscle, *HN* hypoglossal nerve, *HP* hard palate, *LN* lingual nerve, *M* mandible, *MH* mylohyoid muscle, *PGA* palatoglossal arch, *SL* sublingual artery, *SLG* sublingual gland, *SMD* submandibular duct, *SMG* submandibular gland, *SP* soft palate, *T* tongue

Fig. 7 The course of Category P is viewed on the left side from the same angle and in the same frame as those in Fig. 6. The deep lingual artery (DL) continues from the lingual artery passing medial to the hyoglossus (HG). But the sublingual artery (SL) pierces the mylohyoid (MH) to reach the lingual surface of the mandible (M). This case is of Type P-1, because no communication is found between the two arteries. Although not shown in the figure, SL of this case arose from the submental artery just before piercing the mylohyoid. *DL* deep lingual artery, *GG* genioglossus muscle, *GH* geniohyoid muscle, *HG* hyoglossus muscle, *HN* hypoglossal nerve, *HP* hard palate, *LN* lingual nerve, *M* mandible, *MH* mylohyoid muscle, *SL* sublingual artery, *SLG* sublingual gland, *SMG* submandibular gland, *T* tongue

Fig. 8 The course of Type P-2 is viewed on the left side in the same manner as in Fig. 7. In this Type, a communicating branch (CB) is found between the sublingual artery (SL) piercing the mylohyoid (MH) to reach the lingual surface of the mandible (M) and the deep lingual artery (DL) appearing from medial to the hyoglossus (HG). *CB* communicating branch, *DL* deep lingual artery, *HG* hyoglossus muscle, *HN* hypoglossal nerve, *LN* lingual nerve, *M* mandible, *MH* mylohyoid muscle, *SL* sublingual artery, *SMD* submandibular duct, *T* tongue, *V* vein

Fig. 9 All possible routes that enable the sublingual artery and its relevant arteries to reach their destinations are shown in a diagrammatic drawing. The routes are based on the findings obtained in the present study. Each type of course of the sublingual artery in Figs. 1 to 3 is drawn on the basis of this drawing. The external and internal common arteries are drawn in double line. Arteries drawn in bold lines, the proximal portions of the facial and lingual arteries, and the submental artery, are stable vessels having few variations. *CC* common carotid artery, *DL* deep lingual artery, *DoL* dorsal lingual arteries, *EC* external carotid artery, *F* facial artery, *HG* hyoglossus muscle, *IC* internal carotid artery, *L* lingual artery, *MH* mylohyoid muscle, *SL* sublingual artery, *SM* submental artery

Table 1 Number and ratio of occurrence of each type of course of the sublingual artery

Usual or unusual types	Usual	Unusual				Not applicable
Categories	M	L		P		
Types	M-1	L-1	L-2	P-1	P-2	
Number of sides	61	16	1	17	2	4 [a]
Ratio of occurrence (%)	60.4	15.8	1.0	16.8	2.0	4.0
Subtotal of the ratio (%)	60.4	16.8		18.8		4.0

[a] In the 4 sides, their arterial courses were considered as variation of the lingual artery itself, and therefore excluded from the classification.

Table 2 Sexual difference, laterality and bilateral occurrence of usual and unusual types, excluding side or cadaver having the variant lingual artery

	Sexual difference		Laterality		Bilateral occurrence
	Male	Female	Left	Right	
	Detected/examined sides (%)				Detected/examined[a] cadavers (%)
Usual type	27/52 (51.9)	34/45 (75.6)	33/51 (64.7)	28/46 (60.9)	24/31 (77.4)
Unusual type	25/52 (48.1)	11/45 (24.4)	18/51 (35.3)	18/46 (39.1)	13/20 (65.0)

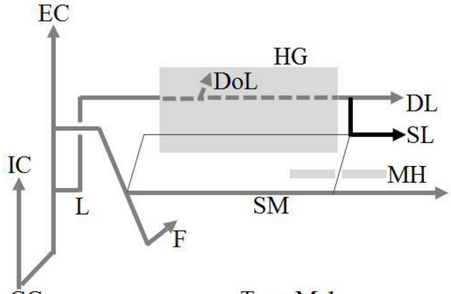
[a] The number of examined cadavers in bilateral occurrence equals the sum number of the bilateral and unilateral occurrence of each type.

Table 3 Thickness of the lingual, facial and submental arteries, comparing the case having the sublingual artery and the case not having it, respectively

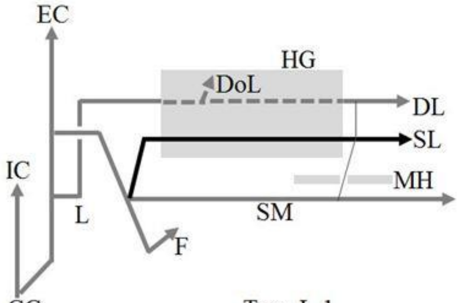
	Lingual artery mm (N)	Facial artery mm (N)	Submental artery mm (N)
Having the sublingual artery	2.53 ± 0.30 (28)	2.68 ± 0.18 (25)	2.11 ± 0.40* (16)
Not having the sublingual artery	2.38 ± 0.34 (25)	2.56 ± 0.36 (25)	1.54 ± 0.30* (34)

Values are denoted as the mean ± SD

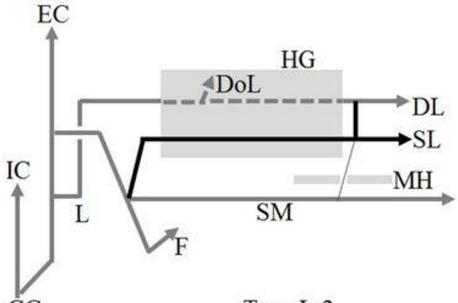
* The values in the same row showed significant difference ($P < 0.05$).



Type M-1



Type L-1



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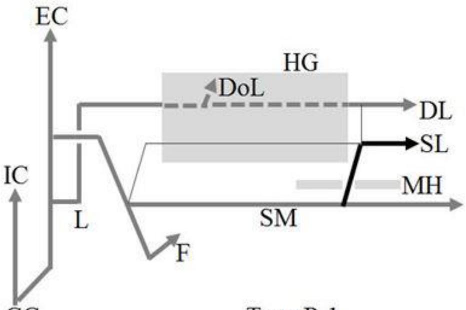

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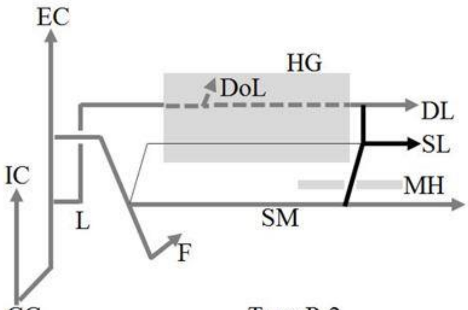

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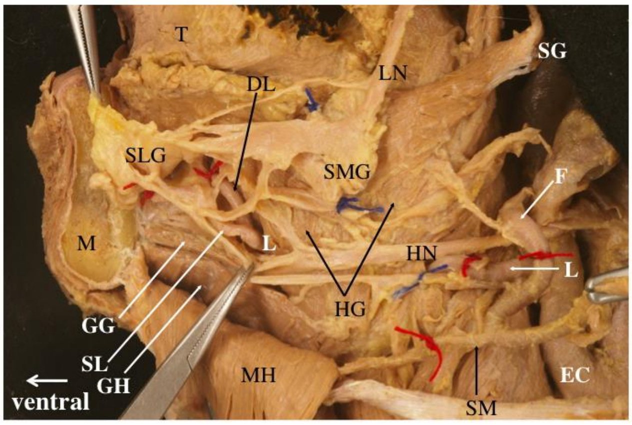
T
SG
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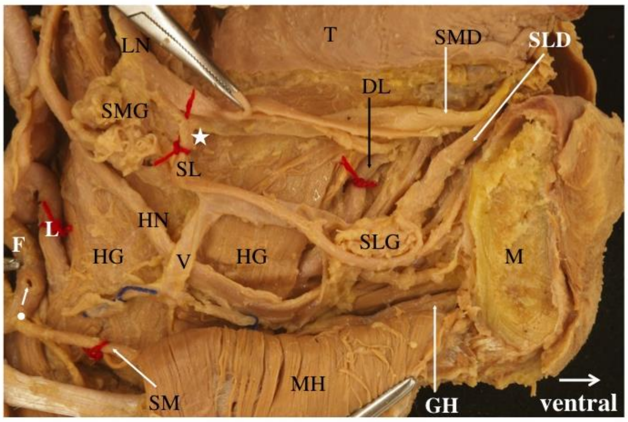
DL
SLG
SMG
F
M
L
HN
L
HG
GG
SL
GH
MH
EC
SM
ventral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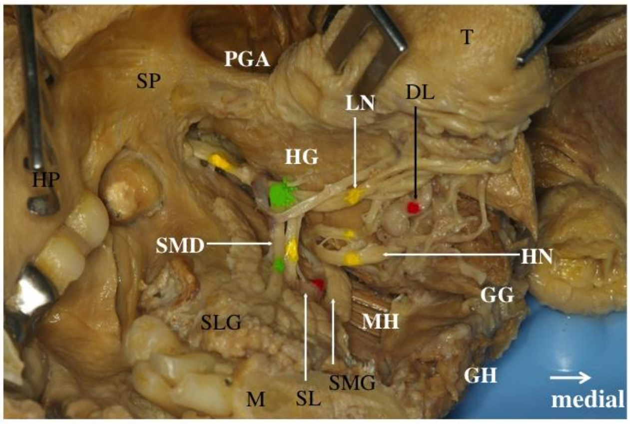
LN
SMD
SLD
DL
SMG
SL
HN
L
F
HG
V
HG
SLG
M
SM
MH
GH
ventral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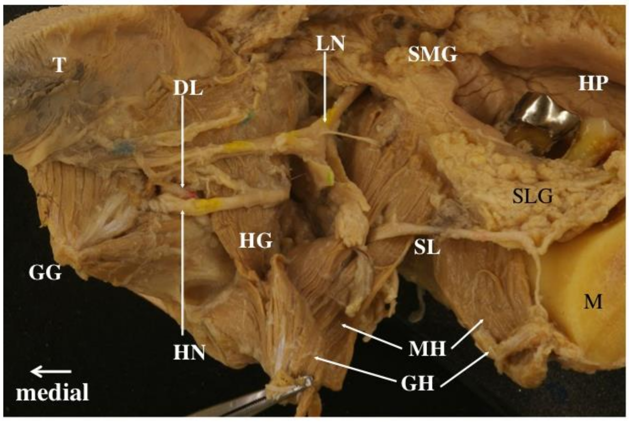
PGA
SP
LN
DL
HG
HP
SMD
HN
GG
SLG
MH
GH
M
SL
SMG
medial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SMG
HP
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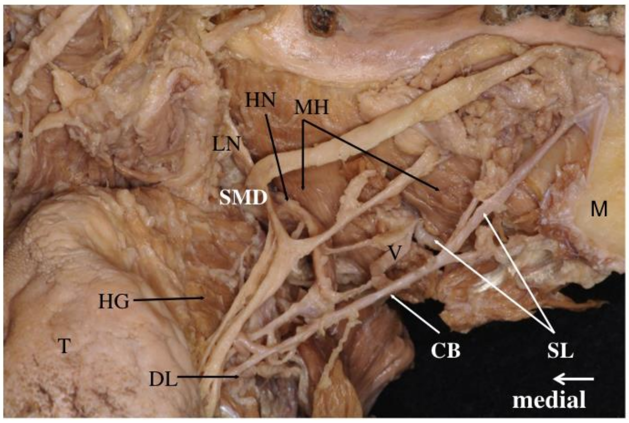
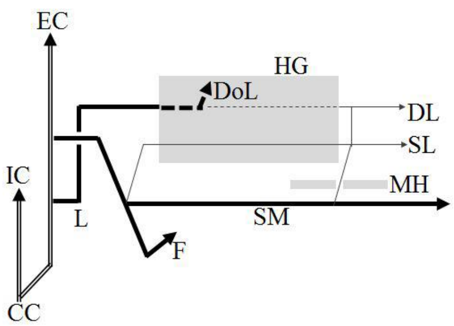
HG
SL
GG
M
HN
MH
GH
medial


HN
MH
LN
SMD
M
V
HG
T
CB
SL
DL
medial


EC
HG
DoL
DL
SL
IC
MH
L
SM
F
CC