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REVIEW ARTICLE

Anatomy of the fasciae and fascial spaces of the maxillofacial and the anterior neck regions

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Abstract This review provides an overview of comprehensive knowledge regarding the anatomy of the fasciae and fascial spaces of the maxillofacial and the anterior neck regions, principally from the standpoint of oral surgery, whose descriptions have long been puzzling and descriptively much too complex. The maxillofacial and the anterior neck regions are divided into four portions: the portions superficial and deep to the superficial layer of the deep cervical fascia (SfDCF) including its rostral extension to the face, the intermediate portion sandwiched by the splitting SfDCF, and the superficial portion peculiar to the face where the deep structures open on the body surface to form the oral cavity. Different fascial spaces are contained in each of the portions, although the spaces belonging to the portion of the same depth communicate freely with each other. The spaces of the superficial portions are adjacent to the oral cavity and constitute the starting point of deep infections from that cavity. The spaces of the intermediate portion lie around the mandible and occupy the position connecting the superficial and deep portions. Among these spaces, the submandibular and prestyloid spaces play an important role as relay stations conveying the infections into the deep portion. The spaces of the deep portion lie near the cervical viscera and communicate inferiorly with the superior mediastinum, among which the poststyloid space plays a role as a reception center of the infections and conveys the infections into the superior mediastinum particularly by way of the retrovisceral space and the carotid sheath.

Keywords Fascia · Fascial space · Gross anatomy · Maxillofacial region · Anterior neck

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Introduction

In most cases the term fascia applies to the membrane of connective tissue enclosing muscles. However, viscera or vessels and nerves are also enclosed with fascia, in which case the fascia is called the visceral fascia and the neurovascular sheath, respectively. Fascia not only encloses individual muscles but also more largely ensheathes a group of muscles as a whole together with or without other anatomical structures. Consequently, the human body is divided into layers by fasciae, and additionally is subdivided into several compartments enclosed by fasciae. Accordingly, anatomical understanding of the human body in association with those layers or compartments is a convenient and reasonable way to read computed tomographic (CT) images and magnetic resonance imaging (MRI). Likewise, full anatomical knowledge of fasciae is indispensable for surgeons to conduct operations safely, that is, to avoid causing surgical injury to anatomical structures overlying a fascia they must be lifted together with the fascia, and also to protect anatomical structures underlying a fascia from surgical injury, that fascia must be left intact.

The compartment formed in association with a fascia is the fascial space. However, in this review the compartments containing a muscle or muscles exclusively are not regarded as fascial space. In the compartment in which muscles and the fibro-adipose tissue portions coexist, only

the latter are treated as independent fascial spaces. In view of the fact that fascial spaces constitute not only pathways transmitting vessels and nerves but also those by which infections spread, full knowledge of fascial spaces is indispensable to predict spread patterns of infection and how to deal with them surgically.

To date, the descriptions of the fasciae and fascial spaces of the maxillofacial and the anterior neck regions have been overly complex. This review provides a comprehensive overview of current knowledge regarding the anatomy of the fasciae and fascial spaces of those regions, principally from the standpoint of oral surgery. An anatomy textbook by Hollinshead (1982) is frequently cited in past literature on the fasciae and fascial spaces in the above regions. In the present review, the designations of the fasciae and fascial spaces are based mainly on that textbook, whereas the anatomical findings are based mainly on those previously published in the present author's own book (Kitamura 2009).

Deep fasciae of the maxillofacial and the anterior neck regions

There are three layers of the deep cervical fascia (DCF)—superficial, pretracheal, and prevertebral—in the anterior neck (Fig. 1; Hollinshead 1982; Mori et al. 1982). The superficial layer (SfDCF) covers the front of the neck just below the subcutaneous tissue. The pretracheal layer (PtDCF) envelops the infrahyoid muscles. The prevertebral layer (PvDCF) is located deepest and covers the front of the vertebral column and its associated muscles.

Additionally to the above three DCFs, the visceral fascia enclosing the viscera of the neck is also mentioned as one of the DCFs. The visceral fascia of the pharynx is continuous above with fascia on the outer surface of the buccinator, and they are collectively called the buccopharyngeal fascia. Thus, four DCFs exist in the anterior neck (Fig. 1). The PtDCF, however, might be conceivably regarded as an accessory of the SfDCF, because they adjoin indistinguishably in places exclusive of the suprasternal space and the back of the infrahyoid muscles. Actually, it remains controversial whether the PtDCF belongs to the same group as the SfDCF (Hiatt and Gartner 1987) or belongs to the same group as the visceral fascia (Grodinsky and Holyoke 1938; Levitt 1970; Standring 2008). Hollinshead (1982) and Smoker (1991) stated that the portion of PtDCF covering the superficial surface of the infrahyoid muscles belonged to the former group, while that covering the deep surface belonged to the latter group.

The SfDCF is known to extend upward and to continue to the deep fasciae of the face: the masseteric and

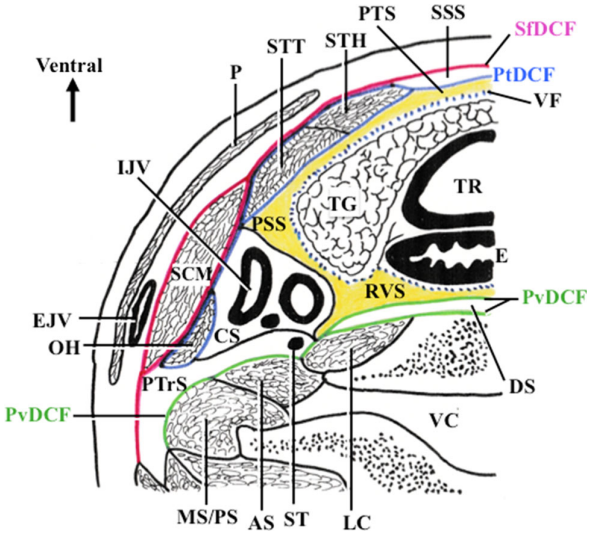

Fig. 1 Layers of the deep cervical fascia shown in horizontal section of the anterior neck at a level below the hyoid bone. A diagrammatic drawing made by Mori et al. (1982) is adopted but altered in accordance with the descriptions of the present review. There are three layers: superficial (SfDCF), pretracheal (PtDCF), and prevertebral (PvDCF), which are represented with *red*, *blue*, and *green lines*, respectively. *Blue dotted line* enclosing the viscera of the neck represents the visceral fascia (VF). The pretracheal (PTS), poststyloid (PSS), and retrovisceral (RVS) spaces are seen to surround the viscera of the neck and collectively constitute the perivisceral space of the neck, which is colored *yellow*. *AS* Anterior scalene, *CS* carotid sheath, *DS* danger space, *E* esophagus, *EJV* external jugular vein, *IJV* internal jugular vein, *LC* logus colli, *MS/PS* middle and posterior scalene, *OH* omohyoid, *P* platysma, *PTrS* posterior triangle space, *SCM* sternocleidomastoid, *SSS* suprasternal space, *ST* sympathetic trunk, *STH* sternohyoid, *STT* sternothyroid, *TG* thyroid gland, *TR* trachea, *VC* vertebral column

the parotid, and finally as far as the temporal (Hollinshead 1982) (Fig. 2). Accordingly, the SfDCF including its upward extension divides the face and anterior neck into superficial and deep portions. However, considering the fact that the SfDCF splits in places to form capsules containing viscera or muscles, and so on (Eisler 1912), or to wrap the ramus of mandible from below and form the closed compartment for the masticatory muscles and the associated fascial spaces (Fig. 2), the intermediate portion sandwiched by the splitting SfDCF should be clearly designated. Hollinshead (1982) called the space formed by the splitting of fascia as an intrafascial space. In the face, the beginning portion of the alimentary canal penetrates the upward extension of the SfDCF to open on the body surface as the oral cavity (Fig. 3). Accordingly, another superficial portion peculiar to the face in which the deep structures open on the body surface should be designated for the submucosal zone of the oral cavity.

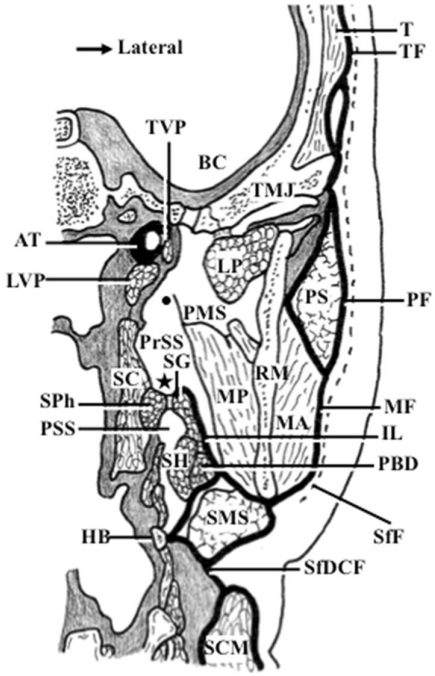

Fig. 2 Head sectioned along a coronal plane passing through the angle of mandible. The superficial layer of the deep cervical fascia (SfDCF) extends upward and continues to the deep fasciae of the face, i.e., the masseteric (MF) and the parotid (PF), as far as the temporal (TF). *Bold line* SfDCF and its upward extension. The SfDCF, including its extension, splits in two places to envelop the submandibular and parotid glands and form the submandibular (SMS) and parotid (PS) spaces, respectively. The SfDCF splits likewise into the outer lamina, corresponding to the MF, and the inner lamina (IL) at the inferior and posterior borders of the ramus of mandible (RM). The two laminae wrap the RM from below and form the closed compartment for the masticatory muscles and the relevant fascial spaces: the pterygomandibular (PMS) and prestyloid spaces (PrSS). *Solid asterisk* Communication site between the PrSS and the poststyloid spase (PSS), *solid circle* thin membrane continuing from the medial pterygoid (MP), shown in the same symbol in Figs. 3 and 9. This schematic drawing is drawn on the basis of the corresponding detailed figure of Lillie and Bauer (1994), as is also the case for Figs. 3, 4 and 7. *AT* Auditory tube, *BC* base of cranium, *HB* hyoid bone, *LP* lateral pterygoid, *MA* masseter, *LVP* tensor veli palatini, *PBD* posterior belly of digastric, *SC* superior constrictor of pharynx, *SCM* sternocleidomastoid, *SfF* superficial fascia, *SG* styloglossus, *SH* stylohyoid, *SPh* stylopharyngeus, *T* temporalis, *TMJ* temporomandibular joint, *TVP* levator veli palatini

The portion superficial to the SfDCF including its rostral extension

The subcutaneous zones of the face and anterior neck are contained in this portion, in which the buccal tissue space containing the buccal fat pad, and the infraorbital tissue space exist as subcutaneous space.

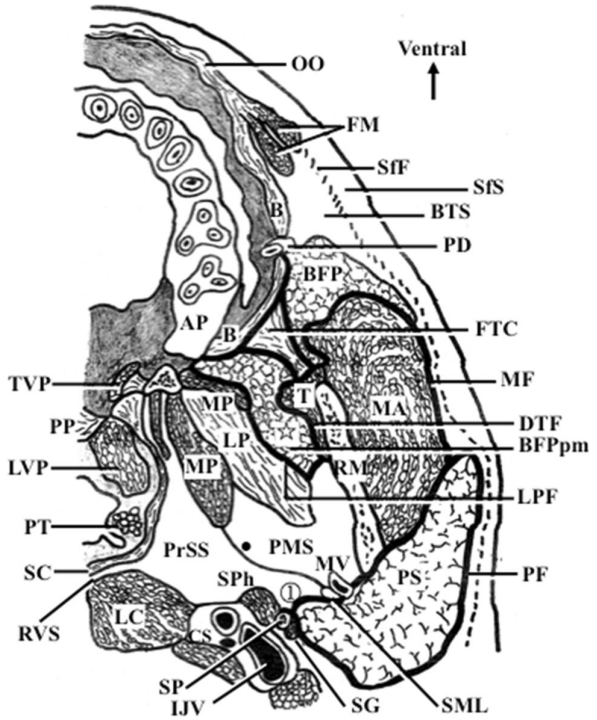

Fig. 3 Head sectioned along a horizontal plane passing through the alveolar process (AP) of maxilla containing the sectioned roots of the dentition. This plate is a view from below. *Bold line* Upward extension of the SfDCF. The subcutaneous zone of the face is subdivided into the superficial stratum (SfS) and the deep stratum by the facial muscles (FM) and the superficial fascia (SfF, dotted line) continuing backward from the FM. The buccal tissue space (BTS) is seen in the deep stratum. The BTS spreads along the buccinator (B), and the posterior portion of it is occupied with the buccal fat pad (BFP). The pterygomandibular process of the BFP (BFPpm) passes backward medial to the temporalis (T) to enter the fascial pocket (*open asterisk*), which is surrounded by the T, the lateral and medial pterygoids (LP and MP) and whose fascia, the deep temporal fascia (DTF) and the lateral pterygoid fascia (LPF), is a continuation from the masseteric fascia (MF) passing across the anterior surface of the temporalis. Near the entrance of the fascial pocket for the BFPpm, the thickened fascia of the anterior surface of the T forming the fascial-tendinous complex (FTC) turns up to cover the outer surface of the B and partly form the bottom of the space for the BFP. Medial to the ramus of mandible (RM), the pterygomandibular space (PMS) is separated from the prestyloid space (PrSS) by the MP and a thin membrane (*filled circle*) connecting the MP and the sphenomandibular ligament (SML). The PMS and PrSS borders on the parotid space (PS) with the intervening fascia indicated with ①, which passes from the styloid process (SP) and the styloglossus (SG) to the posterior border of the RM and attaches to the SML in the middle of its course. As shown in Figs. 6 and 8, the intervening fascia ① is a combined structure of the inner lamina of the SfDCF and the parotid fascia (PF). *CS* Carotid sheath, *IJV* internal jugular vein, *LC* logus colli, *LVP* levator veli palatini, *MA* masseter, *MV* maxillary vessels, *OO* orbicularis oris, *PD* parotid duct, *PP* palatopharyngeus, *PT* palatine tonsil, *RVS* retrovisceral space, *SC* superior constrictor of pharynx, *SPh* stylopharyngeus, *TVP* tensor veli palatini

The superficial fascia of the face and anterior neck

The subcutaneous zone of the face is subdivided into two strata, superficial and deep, by the facial muscles, and the superficial fascia continuing backward from the facial muscles (Fig. 3). Stuzin et al. (1992) mentioned the superficial facial fascia and the temporoparietal fascia as the superficial fascia of the face. The superficial facial fascia is explained as the superficial musculo-aponeurotic system in *Gray's Anatomy* (Standring 2008). In the anterior neck, the platysma occupies the position of the superficial fascia (Fig. 1). The platysma connects tightly to the subcutaneous tissue above it, but connects loosely to the SfDCF below it; this pattern of connection allows free movement of the skin on the deeper structure of the anterior neck, and the plane of loose connection to the SfDCF further serves as an excellent cleavage plane during dissection, and also as a layer through which cutaneous vessels and nerves pass (Lindner 1986).

The buccal and infraorbital tissue spaces

The deep stratum of the subcutaneous zone of the face is composed of the buccal and infraorbital tissue spaces, whose designations are based on *Gray's Anatomy* (Standring 2008). The two spaces contain an abundance of fibro-adipose tissue. The buccal tissue space spreads along the lateral surface of the buccinator and the posterior portion of it is occupied with the buccal fat pad (Fig. 3). The infraorbital tissue space lies between the attachments to bone of the levator labii superioris and the levator anguli oris, and it continues posteroinferiorly to the buccal tissue space. These two spaces, excluding the buccal fat pad, provide routes for vessels and nerves in the face.

The buccal fat pad

The buccal fat pad lies primarily between the buccinator and the masseter or the ramus of mandible, and also behind the parotid duct. As a whole, however, it shows a wide range of distribution, sandwiching the anterior border of the ramus of mandible and its associated muscles (Fig. 3). It is enveloped with thin membrane to be easily distinguishable from fibro-adipose tissue of the other portions of the buccal tissue space. It has a body lying adjacent to the anterior margin of the ramus and three processes: one extending upward and two extending backward (Lang 1995). The upward process, called the deep temporal fat pad by Stuzin et al. (1989), expands thinly upward and backward on the lateral surface of the temporalis (Fig. 4). One of the backward processes lies on the lateral surface of the masseter with its size variable, while another, called the pterygomandibular process by Lang (1995), passes along the medial surface of the temporalis to reach near the mandibular foramen (Fig. 3). This process lies in the fascial pocket, which is surrounded by the temporalis, the lateral pterygoid, and the medial pterygoid, and whose entrance points forward (Fig. 3). The fascia forming the pocket continues from the masseteric fascia, which crosses over the anterior surface of the temporalis, and turns back inside the medial surface of the temporalis to reach the fascial pocket (Figs. 3, 5). According to Gaughran (1957), the deep temporal fascia covering the medial surface of the temporalis and the lateral pterygoid fascia covering the external surfaces of and around the lateral pterygoid fuse to produce the fascial pocket (Fig. 3). Considering these facts, the author regarded the buccal fat pad as being a structure superficial to the SfDCF including its upward extension (Fig. 3).

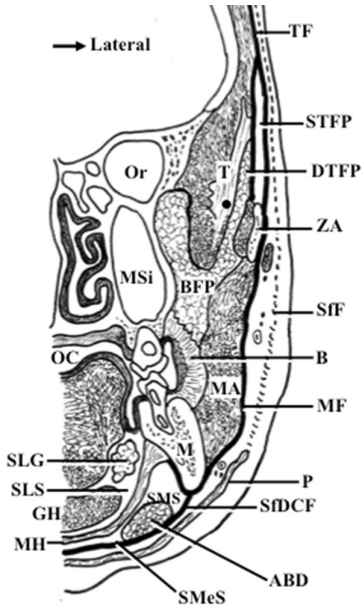

Fig. 4 Head sectioned along a coronal plane passing through the maxillary and mandibular third molar. *Bold line* the superficial layer of the deep cerrical fascia (SfDCF) and its upward extension. Medial to the mandible (M), the sublingual and submandibular spaces (SLS and SMS) are seen above and below the mylohyoid (MH), respectively. The SMS medially borders on the submental space (SMeS) with the anterior belly of the digastric (ABD) intervening. Traced downward, the temporal fascia (TF) splits into two laminae to form the superficial temporal space containing the superficial temporal fat pad (STFP) and then reaches the zygomatic arch (ZA). The deep temporal space lies between the medial lamina of the TF and the lateral surface (*filled circle*) of the temporalis (T), and contains the deep temporal fat pad (DTFP). The DTFP corresponds to the upward process of the buccal fat pad (BFP). *B* Buccinator, *GH* geniohyoid, *MA* masseter, *MF* masseteric fascia, *MSi* maxillary sinus, *OC* oral cavity, *Or* orbital fossa, *P* platysma, *SfF* superficial fascia, *SLG* sublingual gland

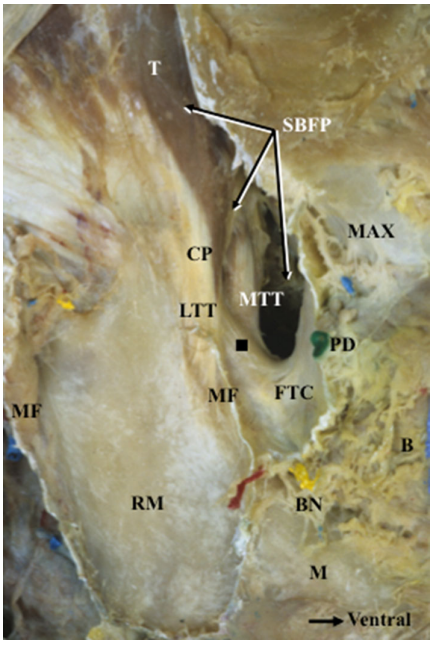

Fig. 5 The fascial-tendinous complex (FTC) connecting the tendons of insertion (LTT and MTT) of the temporalis (T) and the posterior portion of the buccinator (B), viewed from outside. A figure from Kitamura (2009) is reprinted by permission of the publisher (also in Figs. 9, 10). The masseter has been removed and the insertion of the temporalis is visualized clearly. The buccal fat pad has been also removed and the space for the pad (SBFT) is seen to cross over the FTC. The fascia of the FTC (*filled square*) derived from the fascia covering the anterior surface of the temporalis intersects the posterior buccal area to cover the outer surface of the buccinator behind the parotid duct (PD). *BN* Buccal nerve, *CP* coronoid process of mandible, *M* mandible, *MAX* maxilla, *MF* masseteric fascia, *RM* ramus of mandible

The superficial portion peculiar to the face in which the deep structures open on the body surface

This portion corresponds to the oral cavity, the lateral and inferior walls of which are formed by the buccinator and the mylohyoid, respectively. The buccinator is one of the facial muscles. But it is closely aligned with the superior constrictor of the pharynx with the pterygomandibular raphe and the fascial-tendinous complex (FTC; Harn and Shackelford 1982) intervening, and its outer surface is covered with the buccopharyngeal fascia. The FTC is derived from the tendons of insertion of the temporalis and the thickened fascia covering the anterior surface of the temporalis, and it intersects the posterior buccal area to merge into the posterior portion of the buccinator (Harn and Shackelford 1982). It is located near the entrance of the fascial pocket for the pterygomandibular process of the buccal fat pad and forms the bottom of that portion of the space for the fat pad (Figs. 3, 5). The FTC fascia continuing from the masseteric fascia covers the outside of the posterior portion of the buccinators (Figs. 3, 5), which makes the oral cavity appear to penetrate the fascia derived from the SfDCF. The buccal nerve and corresponding vessels pass through a narrow space lying inside the FTC fascia, with its other walls made by the buccinator and the body of mandible (Fig. 5). The space is named the buccotemporal space by Lang (1995). Considering its position in relation to the surrounding fasciae and muscle, it may be the portion corresponding to the perivisceral space of the neck. The orbicularis oris is a forward extension of the buccinator. However, muscle fibers derived from all of the surrounding facial muscles also participate in the formation of the orbicularis oris, Accordingly, the orbicularis oris is considered to be a sphincter formed in collaboration of the alimentary canal wall and the body surface wall.

The sublingual space

The submucosal zone of the oral cavity is contained in the superficial portion peculiar to the face, in which the sublingual space exists as the major submucosal space. The sublingual space is a space rich in fibro-adipose tissue that lies between the muscles of tongue and the mandible and is delineated by the sublingual mucosa from above and by the mylohyoid from below (Fig. 4). The left and right spaces are anteriorly continuous to each other and also communicate through the upper and lower sides of the geniohyoid. It contains the sublingual gland, the sublingual artery, the lingual nerve and veins, a portion of the submandibular gland, and its duct. The hypoglossal nerve and the main trunk of the lingual artery, however, pass deep under the fibrous membrane covering the muscles of the tongue.

The peritonsillar space

The peritonsillar space lying around the palatine tonsil in the lateral wall of the otopharyngeal isthmus may be included in the same category as the sublingual space, although with almost no association with dental infections. It is bounded by the medial surface of the superior constrictor of the pharynx and the mucosa (Standring 2008). Infection of the peritonsillar space readily pass between the scattered muscle bundles of the superior constrictor of the pharynx to spread into the prestyloid space (Fig. 3).

The intermediate portion sandwiched by the splitting SfDCF

Six fascial spaces are contained in this portion as the intrafascial spaces formed by the splitting of the SfDCF as follows: the submandibular, the submental, the parotid, the temporal, the pterygomandibular, and the prestyloid.

Regarding the PtDCF as an accessory of the SfDCF, the suprasternal space, which lies between the two DCFs in the lower anterior neck just above the sternum and is filled with fibro-adipose tissue, may also be included in the category of intrafascial space (Fig. 1).

The submandibular and submental spaces

The two spaces are located just below the sublingual space with the intervening mylohyoid (Fig. 4). The sublingual and submandibular spaces communicate with each other behind the posterior border of the mylohyoid, and also via slits penetrating the mylohyoid through which vessels and nerves come and go between the two spaces. Between the submental and the submandibular spaces, infections are known to spread readily across the anterior belly of the digastric (Grodinsky and Holyoke 1938). The submental space also communicates with the sublingual space via the slits of the mylohyoid for the vessels and nerves. Owing to the close communications among them, the three spaces are collectively treated as one group of spaces in the anatomy textbook written by Hollinshead (1982).

The submental space corresponds to the submental triangle with its roof closed with the SfDCF, and its bottom is formed by the mylohyoid covered with a thin layer of connective tissue seemingly continuing from the SfDCF at the place of the hyoid bone.

The submandibular space is located at the submandibular triangle with its roof closed with the SfDCF, which continues from the roof of the submental space after attaching to the anterior belly of the digastric (Lindner 1986). In the posterior portion of the space, the SfDCF splits to form an intrafascial space exclusively containing the submandibular gland (Fig. 2). Hollinshead (1982) called this intrafascial space "the space of submandibular gland". Figure 6 shows the bottom of the submandibular space. The inferior border of the posterior portion of the space extends inferiorly beyond the intermediate tendon of the digastric, and the bottom of it is formed with the intermediate tendon of the digastric, the stylohyoid, the styloglossus, and the hyoglossus, all of which are covered as a whole with the fascia folded back from the fascia of the roof in its circumference. The portion of the fascia covering the styloglossus passes forward to enter medial to the posterior border of the mylohyoid and continue to the fibrous membrane covering the muscles of tongue in the sublingual space. The anterior portion of the space is the portion for its associated lymph nodes, vessels, and nerves embedded in fibro-adipose tissue. The floor of it is formed by the mylohyoid covered with a thin layer of connective tissue seemingly continuous with that of the floor of the submental space and also with the fascia of the roof.

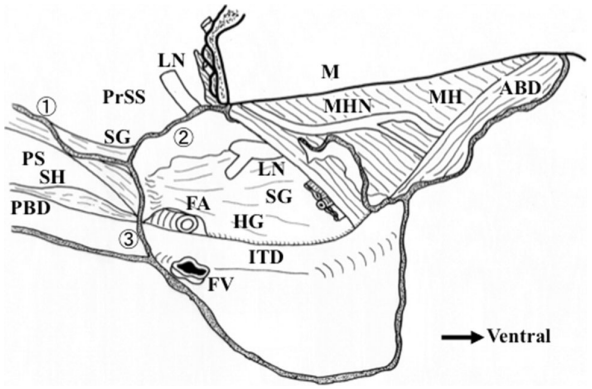

Fig. 6 The bottom of the submandibular space viewed from outside after removing its roof and contents. The bottom of the posterior portion of the space is formed with the intermediate tendon of the digastric (ITD), the stylohyoid (SH), the styloglossus (SG), and the hyoglossus (HG), all of which are covered as a whole with the fascia folded back from the fascia of the roof in its circumference. The bottom of the anterior portion is formed with the mylohyoid (MH), which is covered with a thin layer of connective tissue seemingly continuous from that of the floor of the submental space and also from the fascia of the roof. See Fig. 8 for the portions marked with ① to ③. *ABD* Anterior belly of digastric, *FA* facial artery, *FV* facial vein, *LN* lingual nerve, *M* mandible, *MHN* mylohyoid nerve, *PBD* posterior belly of digastric, *PrSS* prestyloid space, *PS* parotid space

Strictly speaking, the submental space and the anterior portion of the submandibular space may not be the intrafascial space, but I regard them a member of the intrafascial spaces in view of their anatomical situation, i.e., that they are enclosed with the SfDCF and the connective tissue seemingly continuing from the SfDCF. When regarding the mylohyoid as constituting the visceral wall of the oral cavity, however, the above spaces adjacent to the mylohyoid are considered to be a kind of perivisceral space, and the connective tissue covering the outside of the mylohyoid is included in the same category as the buccopharyngeal fascia.

The parotid space

In the region where the parotid gland exists, the SfDCF changes its name to the parotid fascia, and splits to form an intrafascial space called the parotid space, enclosing the parotid gland, its associated lymph nodes, and the facial nerve and great vessels traversing it (Figs. 2, 3, 7). The thick posterior portion of the parotid space fills the retromandibular fossa lying behind the ramus of mandible (Fig. 3). In this fossa, the inner fascia of the space covers the posterior belly of the digastric, the stylohyoid, the styloglossus, and so on (Fig. 8). The external carotid artery and the retromandibular vein passes inward from between the styloglossus and the stylohyoid to enter the poststyloid space adjacent deep to the parotid space. Infections in the

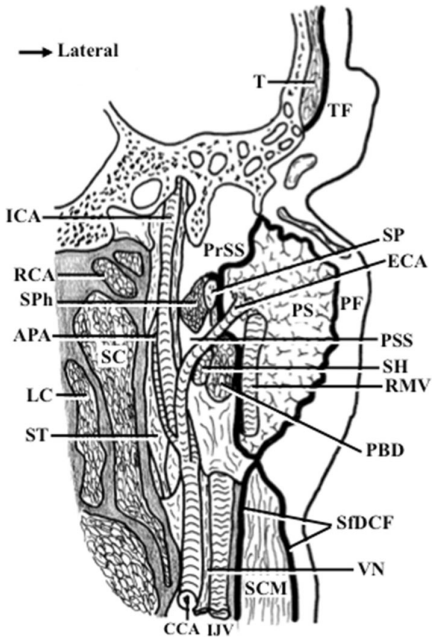

Fig. 7 Parotid space (PS) and its surroundings shown in coronal section passing through the retromandibular fossa immediately behind the ramus of mandible. The superficial layer of the deep cervical fascia (SfDCF, *bold line*) changes its name to the parotid fascia (PF) and splits to form the PS enclosing the parotid gland. The PS fills the retromandibular fossa, and borders medially on the prestyloid and poststyloid spaces (PrSS and PSS). *APA* Ascending pharyngeal artery, *CCA* common carotid artery, *ECA* external carotid artery, *ICA* internal carotid artery, *IJV* internal jugular vein, *LC* logus colli, *PBD* posterior belly of digastric, *RCA* rectus capitis anterior, *RMV* retromandibular vein, *SC* superior constrictor of pharynx, *SCM* sternocleidomastoid, *SH* stylohyoid, *SP* styloid process, *SPh* stylopharyngeus, *ST* sympathetic trunk, *T* temporalis, *TF* temporal fascia, *VN* vagus nerve

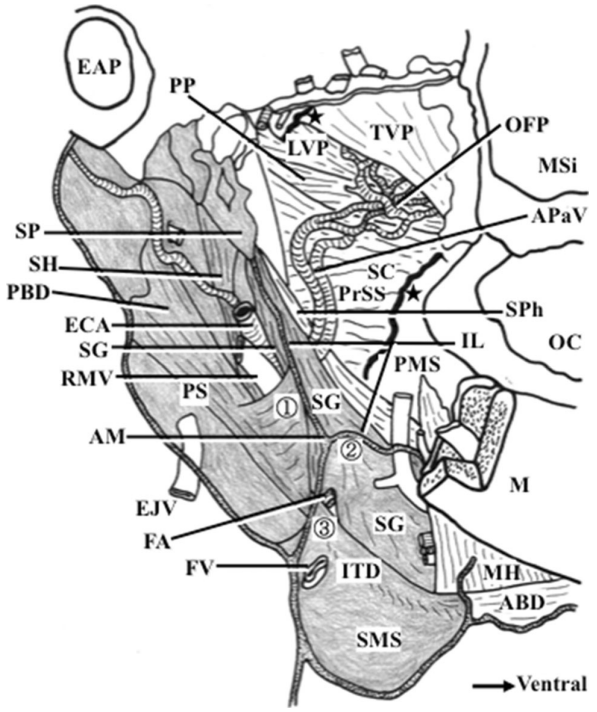

Fig. 8 Bottoms of the prestyloid, parotid and submandibular spaces (PrSS, PS and SMS), PS and SMS viewed from outside. The ramus of mandible and its associated muscles are removed to visualize the PrSS, and the roofs and contents are removed in the PS and SMS. The portions covered with the fasciae continuing from the SfDCF are *lightly shaded*. The PS and SMS are formed by the splitting of the SfDCF into outer and inner fasciae. The inner fascia of the PS covers its bottom formed with the posterior belly of the digastric (PBD), the styloid process (SP), the stylohyoid (SH), the styloglossus (SG), and so on. The SfDCF splits likewise into two laminae, outer and inner, at the inferior and posterior borders of the ramus of mandible. The outer lamina has been already removed, together with the ramus. The inner lamina (IL) passes medially from the borders of the ramus and fuses with the fasciae covering the SG. The PrSS, PS and SMS are separated from each other by the three fascial partitions ① to ③ radiating from the angle of mandible (AM). These partitions are a combined structure formed by joining of adjoining fasciae. A thin fibrous membrane descending obliquely from posterior to anterior and fusing with the visceral fascia of the superior constrictor of the pharynx (SC) has been removed, and its cut ends are marked with *asterisks*. In the Ostmann's fat pad (OFP), adipose tissue is removed to expose the vascular plexus of the ascending palatine vessels (APaV) embedded in it. *ABD* Anterior belly of digastric, *EAP* external acoustic pore, *ECA* external carotid artery, *EJV* external jugular vein, *FA* facial artery, *FV* facial vein, *ITD* intermediate tendon of digastric, *LVP* levator veli palatini, *M* mandible, *MH* mylohyoid, *MSi* maxillary sinus, *OC* oral cavity, *PMS* pterygomandibular space, PP palatopharyngeus, *RMV* retromandibular vein, *SPh* stylopharyngeus, *TVP* tensor veli palatini

parotid space are known to spread readily into the poststyloid space (Coller and Yglesias 1935; Grodinsky and Holyoke 1938), suggesting that the route of the above vessels may be concerned with the deep spread of infections. The parotid space borders on the pterygomandibular and prestyloid spaces with the intervening parotid fascia indicated with ① in Fig. 3, which passes from the styloid process and the styloglossus to the posterior border of the ramus, and attaches to the sphenomandibular ligament in the middle of its course. The maxillary artery and vein pierce the fascia lateral to the ligament to enter the pterygomandibular space, whereas the fascia medial to the ligament is thin so that this portion conceivably forms a pathway of communication with the prestyloid space.

The SfDCF extending upward over the mandible

The SfDCF splits into two laminae, outer and inner, at the inferior and posterior borders of the ramus of mandible (Fig. 2). The outer lamina passes upward along the outer surface of the masseter as the masseteric fascia to cover that muscle, and it further extends beyond the zygomatic arch to change its name to the temporal fascia. The inner lamina (see also Fig. 8) passes medially medial and posterior to the medial pterygoid and finally fuses with the

fasciae covering the styloglossus and around it. The stylomandibular ligament appears to be included in the portion of the inner lamina arising from the posterior border of the ramus of mandible. Hollinshead (1982) described the inner lamina as ascending along the medial surface of the medial pterygoid to reach the cranial base. But we could not verify such a finding. The masticatory muscles connect between the ramus of mandible and the cranial base. Accordingly, the SfDCF covers the area of the masticatory muscles from below (Fig. 2) to form a large intrafascial space treated as "the masticatory space" in the anatomy textbook by Hollinshead (1982). The inner lamina separates the masticatory space from the submandibular and parotid spaces (Fig. 8). The fascia indicated with ① in Fig. 3 corresponds to the combined portion of the inner lamina arising from the posterior border of the ramus of mandible and the parotid fascia. In the masicatory space, three subsidiary spaces, filled with fibro-adipose tissue, exist among the masticatory muscles as follows: the temporal, the pterygomandibular, and the prestyloid spaces.

Also in the inferior border of the body of mandible, the SfDCF splits into the two laminae, the outer lamina that ends at the inferior border, and the inner lamina that extends up to the origin of the mylohyoid (Fig. 4; Hollinshead 1982).

The temporal space

The temporal space is produced in association with the temporal fascia. That fascia arises from the superior temporal line as a continuation of the periosteum. Traced downward, it converges and splits into two laminae, lateral and medial, which are attached to the lateral and medial surfaces of the zygomatic arch, respectively, and the interval between them is filled with fibro-adipose tissue (Fig. 4). That interval is the superficial temporal space and the fibro-adipose tissue contained in it is called the superficial temporal fat pad (Stuzin et al. 1989). The deep temporal space lies between the medial lamina of the temporal fascia and the lateral surface of the temporalis. The fibro-adipose tissue contained in it is called the deep temporal fat pad (Stuzin et al. 1989). This pad corresponds to the upward process of the buccal fat pad (Gaughran 1957; Lillie and Bauer 1994), therefore the deep temporal space might be more properly regarded to be a portion of the buccal tissue space. The deep temporal fascia, which was described by Gaughran (1957) as covering the medial surface of the temporalis, has the possibility of covering the lateral surface of the muscle as well (solid circle in Fig. 4; Ohta and Baba 1996), although it is a delicate connective tissue film visible, if at all, only with much difficulty on the lateral surface. Accordingly, the deep temporal space may be a fascial pocket produced by fusion of the two kinds of the temporal fascia (Fig. 4), whose orifice opens downward into the buccal fat pad.

The pterygomandibular space

The pterygomandibular space is an area of fibro-adipose tissue located between the medial and lateral pterygoids medially and the ramus of mandible and the temporalis laterally, and it contains the pterygoid venous plexus, the maxillary artery and vein, and the mandibular nerve. The pterygomandibular space is not so large as it is generally conceived, because inside the ramus of mandible, the buccal fat pad occupies a considerably wide area as far as the site near the mandibular foramen (Fig. 3). Anteriorly, it is closely aligned with the buccal fat pad with an intervening thin membrane, which appears not to serve as a barrier against local anesthetics (Takasugi 1997). In addition, infections of the buccal tissue space including the buccal fat pad are thought to have not only the possibility of spreading superficially to the infraorbital tissue space and the superficial stratum of the subcutaneous zone of the face, but also the possibility of deeply spreading to the pterygomandibular and temporal spaces (Kostrubala 1945; Mouri et al. 1998). The buccal fat pad and the remaining anterior portion of the buccal tissue space are distinguished with much difficulty in CT and MRI images, but the parotid duct may serve as an indicator for the boundary between them, because it crosses just in front of the buccal fat pad (Fig. 3).

The prestyloid space

The prestyloid space contains an abundance of fibro-adipose tissue. Figure 3 shows its positional relationship to adjacent spaces. It is separated medially from the pterygomandibular space with the medial pterygoid and a thin membrane (solid circle in Fig. 3) continuing from the muscle to reach the sphenomandibular ligament (see also Fig. 9). This membrane is named the medial pterygoid fascia (Lillie and Bauer 1994) or the interpterygoid fascia (Baker and Davies 1972), and was regarded by Hollinshead (1982) as possibly the inner lamina of the SfDCF after splitting at the borders of the ramus of mandible. The superior border of the membrane appears to correspond to the pterygospinosus ligament, which is described by Mérida Velasco et al. (1994) as extending from the posterior border of the lateral lamina of the pterygoid process, coursing below the foramen ovale, to the spine of the sphenoid bone. The prestyloid space communicates with the pterygomandibular space over the ligament just below the foramen ovale (Fig. 9). Posterolaterally, it is separated from the parotid space by the combined membrane of the inner lamina of the SfDCF and the parotid fascia (① in

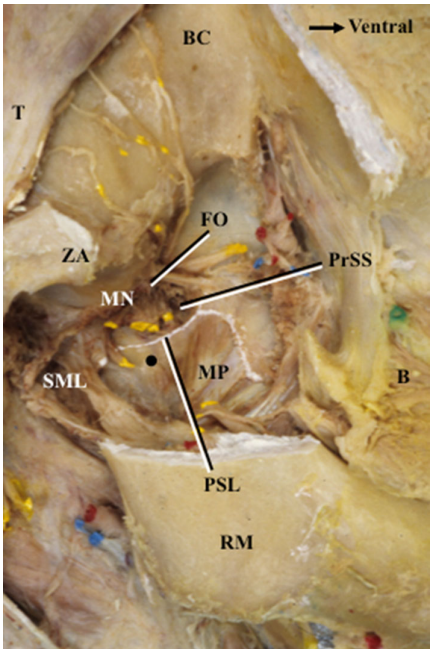

Fig. 9 The medial wall of the pterygomandibular space viewed from outside after removing the upper half of the ramus of mandible (RM) and the lateral pterygoid (LP). The medial wall is formed with the medial pterygoid (MP) and a thin membrane (*filled circle*) continuing from the MP to reach the sphenomandibular ligament (SML). The superior border of this membrane is the pterygospinosus ligament (PSL). The prestyloid space (PrSS) is located inside of the membrane and MP. The pterygomandibular space communicates with the PrSS over the PSL just below the foramen ovale (FO). *B* Buccinator, *BC* base of cranium, *MN* mandibular nerve, *T* temporalis, *ZA* zygomatic arch

Figs. 3, 6, 8). Posteriorly, it borders on the anterior wall of the carotid sheath (Fig. 3). It borders medially on the pharyngeal cavity with an intervening thin sheet of the superior constrictor of the pharynx and opens into the retrovisceral space behind the pharynx. It communicates below with the poststyloid space lying deep to the SfDCF (Fig. 2). The two spaces are generally combined and are collectively called the parapharyngeal space (Nonomura 1998), the reason for which may be that they show similar positional relationships to the pharynx or the esophagus and also the retrovisceral space. Accordingly, the prestyloid space is generally conceived to be one of the spaces lying deep to the SfDCF. It is, however, separated from the poststyloid space by the styloglossus and stylopharyngeus covered by a fascia with which the SfDPF fuses, with only a small pathway of communication passing between the two muscles and transmitting the ascending palatine vessels (Figs. 2, 8). These findings suggest the possibility that the prestyloid space is a member of the intrafascial spaces instead of the deep spaces. On the other hand, it opens anteroinferiorly into the area lying behind the posterior border of the mylohyoid, into which the sublingual and the

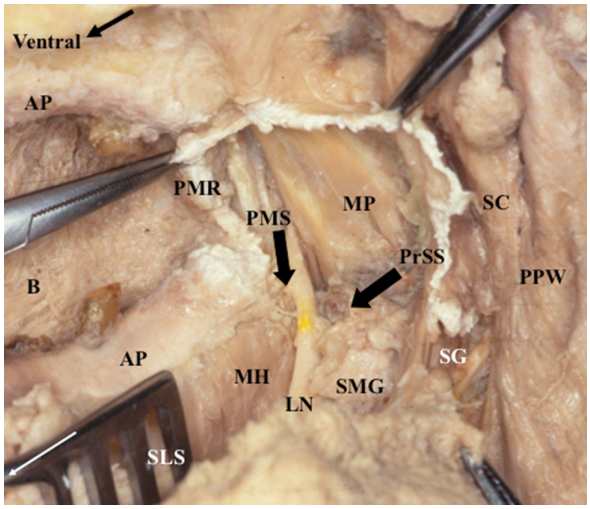

Fig. 10 The area behind the posterior border of the mylohyoid (MH) viewed from above and front after removing the mucosa to expose the structures below it. A portion of the submandibular gland (SMG) is seen to emerge from that area. The sublingual space (SLS) communicates with the submandibular space (SMS) by way of the area. The prestyloid space (PrSS) opens into the area by passing medial to the medial pterygoid (MP). The pterygomandibular space (PMS) also communicates with the area by the route of the lingual nerve (LN) passing lateral to the MP. *AP* Alveolar part or process, *B* buccinator, *PMR* pterygomandibular raphe, *PPW* posterior pharyngeal wall, *SC* superior constrictor of pharynx, *SG* styloglossus

submandibular spaces also open (Fig. 10). Thus, the prestyloid space not only borders on many spaces and the pharyngeal cavity but also communicates with the spaces relevant to the oral cavity, suggesting that it occupies an important position when considering the deep spread of infections from pharyngeal or oral cavities.

A thin fibrous membrane passes anteroinferiorly toward the superior constrictor of the pharynx on the inner wall of the prestyloid space (Fig. 8). The membrane, which was studied in details by Takezawa and Kageyama (2012), arises from the inferior surface of the petrosus part of the temporal bone, and joins the visceral fascia on the lateral surface of the superior constrictor. Above the upper border of the superior constrictor, a vascular plexus of the ascending palatine vessels embedded in fibro-adipose tissue fills the area that lies between the tensor veli palatini and the levator veli palatini with its bottom formed by the palatopharyngeus (Fig. 8). This fibro-adipose tissue is the Ostmann's fat pad according to a figure made by Kriens (1975), which is thought to play an important role in normal closure of the auditory tube (Takasaki et al. 2002).

The fascial partitions among the intrafascial spaces lying around the ramus of mandible

The submandibular, parotid, pterygomandibular, and prestyloid spaces are separated from each other by three

fascial partitions radiating from the angle of mandible (① to ③ in Figs. 6, 8). These partitions are continuations of the SfDCF, and connect the portion of the SfDCF covering the outer surface of the region around the ramus of mandible and the portion of it overlying the inner wall of the above intrafascial spaces. They are a combined structure formed by joining of adjoining fasciae. In partitions ① and ②, the inner lamina of the SfDCF, after splitting at the borders of the ramus of mandible, joins the inner wall fasciae of the parotid and submandibular spaces, respectively. In partition ③, the inner wall fascia of the parotid space and that of the submandibular space join. The fasciae of the inner walls and the inner lamina of the SfDCF fuse with the fasciae enveloping the posterior belly and the intermediate tendon of the digastric, the stylohyoideus, and the styloglossus. Although further research is necessary to know how and to what extent the SfDCF fuses with the fasciae enveloping the underlying muscles, the above finding suggests that the SfDCF utilizes these muscles as sites of attachment. Lindner (1986) also described a finding similar to that. It is known that the external carotid artery seldom passes lateral to the posterior belly of the digastric and the stylohyoid (Kawai 2016). This finding suggests that the SfDCF attaching to these muscles from outside does not allow the external carotid artery, and probably also its branches, to pass lateral to the muscles.

The portion deep to the SfDCF

The deep fascial spaces lying in this portion are the poststyloid space, the pretracheal space, the retrovisceral space, the carotid sheath, and the posterior triangle of the neck. The trigonum scalenovertebrale (Miyaki et al. 2008), seemingly taking a deep location outside of the range of this portion, is also described in this section.

The perivisceral spaces of the neck: the poststyloid, pretracheal and retrovisceral spaces

These three spaces are intercommunicating spaces surrounding the viscera of the neck (Fig. 1) and collectively constitute the perivisceral space of the neck. Considering its positional relationship to the pharynx, the prestyloid space may also have to be included in the perivisceral space (Fig. 3). Actually Hollinshead (1982) collectively called the prestyloid space, the retropharyngeal space, and the sublingual and submandibular spaces the peripharyngeal space. The inclusion of the latter two into this space is conceivably based on their close communication with the prestyloid space.

The poststyloid space is a narrow space lying between the viscera of the neck covered with the visceral fascia and the carotid sheath at the level below the styloglossus and the stylopharyngeus. In contrast to the prestyloid space, it is filled with vessels and nerves embedded in a smaller amount of fibro-adipose tissue. The vessels and nerves contained are branches or tributaries of the major vessels and nerves of the neck, almost all of which come and go between the poststyloid space and adjacent intrafascial spaces. Therefore the poststyloid space can be said to be an important place where pathways of communication from the adjacent spaces gather. It opens medially into the retrovisceral space (Fig. 1) and communicates below with the pretracheal space through the route of the superior thyroid vessels. It is clinically regarded as including the carotid sheath in its territory (Nonomura 1998), because the sheath is radiologically delineated only with much difficulty. It extends posterosuperiorly as a potential cleavage between the carotid sheath and the posterior belly of the digastric enveloped by the fascia with which the SfDCF fuses, by way of which cleavage the occipital artery is transmitted as far as the occipital region.

The pretracheal space lies ventral to the viscera of the neck in the lower median neck. Viewed from front, it is surrounded by the thyroid gland and the left and right carotid sheaths, and is filled with an abundance of fibro-adipose tissue. It is covered with the infrahyoid muscles and their fascia (PtDCF) (Fig. 1). It is described to extend superiorly as far as the attachment of the infrahyoid muscles to the thyroid cartilage by way of the potential cleavage between the infrahyoid muscles enclosed with the PtDCF and the visceral fascia of the thyroid gland (Standring 2008). It extends inferiorly into the anterior portion of the superior mediastinum, at the bottom of which the posterior surface of the sternum and the fibrous pericardium are united by denser connective tissue (Hollinshead 1982). The inferior end of its extent is around the fourth thoracic vertebra (Grodinsky and Holyoke 1938).

The retrovisceral space is a space of cleavage lying between the PvDCF and the dorsal visceral fasciae of the pharynx and esophagus (Fig. 1), the two DCFs being connected with loose connective tissue. The upper portion of it is the retropharyngeal space, while the lower portion is the retroesopharyngeal space (Hollinshead 1982). It extends upward behind the pharynx to the base of the skull, and inferiorly extends into the posterior portion of the superior mediastinum, at the bottom of which it is obliterated through fusion of the connective tissue on the dorsal surface of the esophagus to the PvDCF (Hollinshead 1982). The inferior end of its extent varies from the sixth cervical to the fourth thoracic vertebral level (Grodinsky and Holyoke 1938). The retrovisceral space is said to be an important pathway by which infections originating from various locations of the head and neck reach the posterior portion of the superior mediastinum (Moncada et al. 1978; Hollinshead 1982).

The PvDCF splits anteroposteriorly into two laminae on the ventral surface of the vertebral column to form an intrafascial

space (Fig. 1). The anterior lamina of the splitting PvDCF and the intrafascial space are called the alar fascia and the danger space, respectively, in the anatomy textbook by Hollinshead (1982). The danger space is a zone of delicate loose connective tissue extending behind the retrovisceral space from the base of the skull to as far as the diaphragm, and is also said to be an important pathway for infections to reach the posterior portion of the superior mediastinum (Moncada et al. 1978; Hollinshead 1982). Clinically, the danger space is often considered together with the retrovisceral space because they cannot be differentiated radiologically (Standring 2008). The potential space behind the PvDCF is the prevertebral space, in which the phrenic nerve exists. But that term has been variably used, so that the danger or retrovisceral space is also occasionally called the prevertebral space.

Carotid sheath

The carotid sheath is interposed between the SfDCF, adhered closely by the PtDCF, and the PvDCF at the level below the styloglossus and stylopharyngeus (Fig. 1). At the level above those muscles (Fig. 3), however, it borders anteriorly on the prestyloid space, and the ascending pharyngeal vessels and the glossopharyngeal nerve run longitudinally in the sheath wall facing the space. Lang (1995) also reported a similar finding. These vessels and nerve reach there after passing medial to the posterior belly of the digastric and the muscles originating from the styloid process, and likewise the sheath follows that course. The potential cavity within the carotid sheath may also be an important pathway by which infections originating from various spaces of the head and neck reach the superior mediastinum (Moriwaki et al. 2002).

The posterior triangle of the neck

The posterior triangle of the neck is delimited anteriorly by the sternocleidomastoid, posteriorly by the trapezius, and inferiorly by the clavicle. The fascial space formed in this triangle has been called the posterior neck space (Ichimura 2009), although not generally. Its roof is formed with the SfDCF, while its floor is formed with the splenius capitis, the levator scapulae, and the scalene muscles, and is overlaid as a whole with the PvDCF (Fig. 1). It is quite difficult to expose the SfDCF in the posterior triangle of the neck, as the SfDCF of this triangle is not overlain by the platysma connecting loosely with the SfDCF. But Zhang and Lee (2002) suggested the possibility that the SfDCF did not exist between the sternocleidomastoid and trapezius. The posterior triangle is adjacent posterior to the carotid sheath, and its lower portion especiallyis filled with an abundance of fibro-adipose tissue containing various vessels, nerves and lymph nodes. The cervical sympathetic trunk runs longitudinally in the medialmost portion of the posterior triangle lying behind the carotid sheath (Fig. 1), where it is attached to the PvDCF (Lang 1995) or the posterior wall of the sheath (Lindner 1986). Hollinshead (1982) stated that the posterior triangle was of little clinical importance since it communicated with no other space in the neck, although Ichimura (2009) mentioned the carotid sheath and the retrovisceral space as spaces communicating with it. But it appears to be important from the perspective of surgery for radical neck dissection because numerous lymph nodes belonging to the deep cervical nodes are embedded in the connective tissue of the carotid sheath and also in its fibro-adipose tissue.

The trigonum scalenovertebrale

At its lower medial angle, the posterior triangle of the neck communicates with the deeper portion through the opening between the carotid sheath and the anterior scalene overlaid with the PvDCF. This opening lies just behind the junction of the internal jugular vein with the subclavian vein, and the first rib forms its bottom. The transverse cervical vessels and the phrenic nerve go in and out through the opening. The deeper portion inside the opening is a space of triangular pyramid shape lying above the cervical pleura and described as the trigonum scalenovertebrale in the study of Miyaki et al. (2008). It is delimited laterally and posteriorly by the scalene muscles and medially by the viscera of the neck and the vertebral column, and its anterior aspect is covered with the carotid sheath. The bottom of the trigonum is formed by the suprapleural membrane (Fig. 11), which is a condensation of endothoracic fascia covering the cervical pleura (Gaughran 1964) and serves to strengthen the pleura (Gatzoulis 2008). The trigonum borders medially on the pretracheal space with the carotid sheath intervening and contains the following vessels: the vertebral vein, the subclavian artery, and its branches (Fig. 11). The suprapleural membrane is attached along the internal border of the first rib, and further it is suspended by three fibrous bands, which are derived from the PvDCF and arise from the transverse process of the seventh cervical vertebra, the neck of the first rib, and the ventral surface of the seventh cervical to first thoracic vertebrae, respectively (Gaughran 1964). These findings suggest that the trigonum may be the structure lying outside of the PvDCF.

Intercommunications among the fascial spaces and infection pathways from oral cavity to the superior mediastinum (Fig. 12)

Figure 12 shows intercommunications that can be anatomically presumed to exist among the fascial spaces of the maxillofacial and the anterior neck regions, and

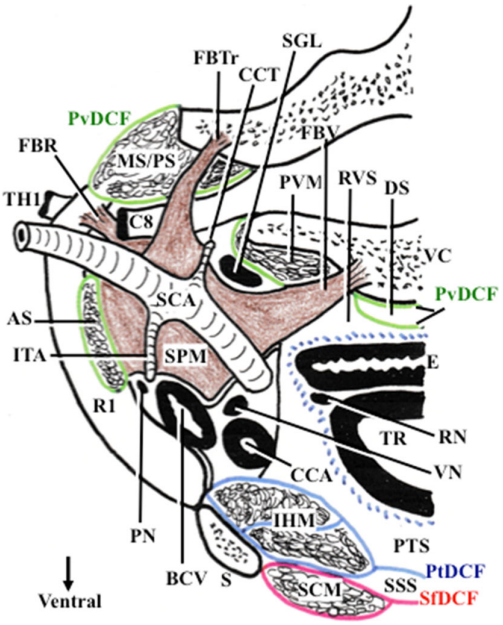

Fig. 11 The bottom of the trigonum scalenovertebrale and its surroundings viewed from above, the findings of which are based on our previous study (Kitamura et al. 2009). The bottom is formed with the suprapleural membrane (SPM) overlying the cervical pleura. The SPM, colored *brown*, is attached along the internal border of the first rib (R1), and is further suspended by three fibrous bands arising from the transverse process of the seventh cervical vertebra (FBTr), the neck of the R1 (FBR), and the anterior surface of the seventh cervical to first thoracic vertebrae (FBV), respectively. *AS* Anterior scalene, *BCV* brachiocephalic vein, *C8* eighth cervical nerve, *CCA* common carotid artery, *CCT* costocervical trunk, *DS* danger space, *E* esophagus, *IHM* infrahyoid muscles, *ITA* internal thoracic artery, *MS/PS* middle and posterior scalene, *PN* phrenic nerve, *PtDCF* pretracheal layer of deep cervical fascia, *PTS* pretracheal space, *PvDCF* prevertebral layer of deep cervical fascia, *PVM* prevertebral muscles, *RN* recurrent nerve, *RVS* retrovisceral space, *S* sternum, *SCA* subclavian artery, *SCM* sternocleidomastoid, *SfDCF* superficial layer of deep cervical fascia, *SGL* stellate ganglion, *SSS* suprasternal space, *TH1* first thoracic nerve, *TR* trachea, *VC* vertebral column, *VN* vagus nerve

possible infection pathways from the oral cavity to the superior mediastinum are also shown. Spread of infection occurs by way of pathways of communication between adjacent spaces. Routes for transmitting vessels and/or nerves as well as places where fascial wall is absent or thin are mentioned as the pathways of communication.

Infections from the oral cavity spread initially to the subcutaneous spaces lying in the portion superficial to the SfDCF or the major submucous space of the oral cavity, that is, the sublingual space. Spreading further, such infections reach the intrafascial spaces lying in the intermediate portion, in which there are three conceivable pathways by which infections spread: one is by passing from the buccal tissue space to the pterygomandibular

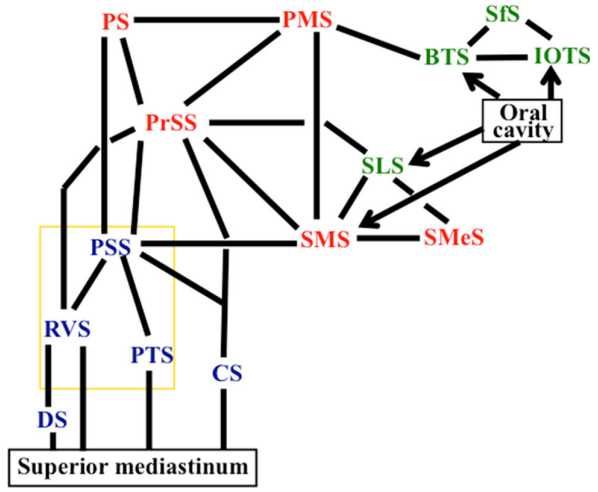

Fig. 12 Intercommunications among the fascial spaces of the maxillofacial and the anterior neck regions shown so as to allow illustration of the infection pathways from the oral cavity to the superior mediastinum. The spaces in the portion superficial to the SfDCF and that in the submucosal zone of the oral cavity are written in *green letters*, those in the portion sandwiched by the splitting SfDCF (intrafascial space) in *red letters*, those in the portion deep to the SfDCF in *blue letters*. The spaces collectively constituting the perivisceral space of the neck are outlined with the *yellow border*. The prestyloid space (PrSS) is generally conceived to be located in the deep portion, but it is described here as one of the intrafascial spaces, viewed from its positional relation to the SfDCF. *BTS* Buccal tissue space, *CS* carotid sheath, *DS* danger space, *IOTS* infraorbital tissue space, *PMS* pterygomandibular space, *PS* parotid space, *PSS* poststyloid space, *PTS* pretracheal space, *RVS* retrovisceral space, *SfS* superficial stratum of subcutaneous zone of face, *SLS* sublingual space, *SMeS* submental space, *SMS* submandibular space

space (Kostrubala 1945; Mouri et al. 1998); next, by passing from the sublingual space to the prestyloid or submandibular spaces; and lastly, by passing directly to the sunmandibular space. As the intrafascial spaces communicate with each other, the infections are conceivably spread more or less readily into the adjacent spaces. Spreading even further, the infections reach the deep fascial spaces lying in the portion deep to the SfDCF, in which occasion the prestyloid and poststyloid spaces serve as relay stations from which the infections are transmitted as far as the superior mediastinum by the retrovisceral space, the danger space, the pretracheal space, and the carotid sheath. The pretracheal, poststyloid, and retrovisceral spaces collectively constitute the perivisceral space (Fig. 1), in which free communications exist around the viscera of the neck, and infections spread readily into the adjacent spaces.

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Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

References

Baker BCW, Davies PL (1972) The applied anatomy of the pterygomandibular space. Br J Oral Surg 10:43–55

Coller FA, Yglesias L (1935) Infections of the lip and face. Surg Gynecol Obstet 60:277–290

Eisler P (1912) Die Muskeln des Stammes. Fischer, Jena

Gatzoulis MA (2008) Thorax. In: Standring S, Borley NR, Cllins P et al (eds) Gray's anatomy: the anatomical basis of clinical practice, 40th edn. Churchill Livingstone Elsevier, Philadelphia, pp 909–1038

Gaughran GRL (1957) Fasciae of the masticator space. Anat Rec 129:383–400

Gaughran GRL (1964) Suprapleural membrane and suprapleural bands. Anat Rec 148:553–559

Grodinsky M, Holyoke EA (1938) The fasciae and fascial spaces of the head, neck and adjacent regions. Am J Anat 63:367–408

Harn SD, Shackelford LS (1982) Further evaluation of the superficial and deep tendons of the human temporalis muscle. Anat Rec 202:537–548

Hiatt JL, Gartner LP (1987) Textbook of head and neck anatomy, 2nd edn. Williams & Wilkins, Baltimore

Hollinshead WH (1982) Anatomy for surgeons: volume 1 the head and neck, 3rd edn. Harper & Row, Philadelphia, pp 269–289

Ichimura K (2009) Fascial spaces of the neck and spread pathways for infections (in Japanese). J Otolaryngol Head Neck Surg 25:1589–1594

Kawai K (2016) Anomalous course of the external carotid artery. Anat Sci Int 91:334–340

Kitamura S (2009) Atlas of oral maxillofacial region anatomy for dental clinicians (in Japanese). Ishiyaku, Tokyo

Kitamura S, Sumida K, Abe K, Ishikawa T, Yamashita K (2009) Topographic anatomy of the trigonum scalenovertebrale (in Japanese). Jap Res Soc Clin Anat 9:50–51

Kostrubala MJG (1945) Potential anatomical spaces in the face. Am J Surg 68:28–37

Kriens O (1975) Anatomy of the velopharyngeal area in cleft palate. Clin Plast Surg 2:261–283

Lang J (1995) Clinical anatomy of the masticatory apparatus and peripharyngeal spaces. Thieme, New York

Levitt MGW (1970) Cervical fascia and deep neck infections. Laryngoscope 80:409–435

Lillie JH, Bauer BA (1994) Sectional anatomy of the head and neck. A detailed atlas. Oxford University Press, Oxford

Lindner HH (1986) The anatomy of the fascia of the face and neck with particular reference to the spread and treatment of intraoral infections (Ludwig's) that have progressed into adjacent fascial spaces. Ann Surg 204:705–714

Mérida-Velasco JR, Rodríguez-Vázquez JF, Arraez-Aybar L, Jiménez-Collado J (1994) Study of pterygospinosus muscle in human fetuses. Acta Anat (Basel) 151:14–19

Miyaki T, Saitoh T, Hanno S, Sawut A, Itoh M (2008) Trigonum scalenovertebrale: 1. Structure (in Japanese). Jap Res Soc Clin Anat 8:44–45

Moncada R, Warpeha R, Pickleman J et al (1978) Mediastinitis from odontogenic and deep cervical infection. Anatomic pathway of propagation. Chest 73:497–500

Mori O, Ogawa T, Outi H, Mori T (1982) Kaibougaku, vol 1, 11th edn (in Japanese). Kanehara, Tokyo

Moriwaki Y, Sugiyama M, Matsuda G et al (2002) Approach for drainage of descending necrotizing mediastinitis on the basis of the extending progression from deep neck infection to mediastinitis. J Trauma 53:112–116

Mouri M, Shimazu K, Shimizudani K, Murata Y, Murakami H (1998) Anatomy and diagnostic imaging of the buccal space (in Japanese). J Otolaryngol Head Neck Surg 14:687–690

Nonomura N (1998) Anatomy and diagnostic imaging of the parapharyngeal space (in Japanese). J Otolaryngol Head Neck Surg 14:661–667

Ohta K, Baba M (1996) Orbitozygomatic infratemporal approach. In: Hakuba A (ed) Surgical anatomy of the skull base. Miwa Shoten, Tokyo, pp 1–35

Smoker WRK (1991) Normal anatomy of the infrahyoid neck: an overview. Semin Ultrasound CT MR 12:192–203

Standring S (2008) Head and neck. In: Standring S, Borley NR, Cllins P et al (eds) Gray's anatomy: the anatomical basis of clinical practice, 40th edn. Churchill Livingstone Elsevier, Philadelphia, pp 397–703

Stuzin JM, Wagstrom L, Kawamoto HK, Wolfe SA (1989) Anatomy of the frontal branch of the facial nerve. The significance of the temporal fat pad. Plast Reconstr Surg 83:265–271

Stuzin JM, Baker TJ, Gordon HL (1992) The relationship of the superficial and deep facial fascias: relevance to rhytidectomy and aging. Plast Reconstr Surg 89:441–449

Takasaki K, Sando I, Balaban CD, Miura M (2002) Functional anatomy of the tensor veli palatine muscle and Ostmann's fatty tissue. Ann Otol Rhinol Laryngol 111:1045–1049

Takasugi Y (1997) Anterior technique for mandibular nerve block (in Japanese). Quintessence 16:1982–1989

Takezawa K, Kageyama I (2012) Newly identified thin membranous tissue in the deep infratemporal region. Anat Sci Int 87:136–140

Zhang M, Lee ASJ (2002) The investing layer of the deep cervical fascia does not exist between the sternocleidomastoid and trapezius muscles. Oto Head Neck Surg 127:452–457