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Variations of the lingual and inferior alveolar nerves and their anomalous relationship with the maxillary artery

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SUMMARY

The infratemporal fossa is a compact space with multiple contents. Explicit anatomical knowledge regarding the relationship between these neurovascular structures becomes imperative during any surgical intervention. Literature is abounding with variations in this region. It encompasses communication between branches of the mandibular nerve or entrapment of nerves by bony bridges, or even abnormal course and branching pattern of the arteries. However, there are many other variabilities in these structures that are less reported or unreported. The present study is an effort to report the characteristic variations of the lingual and inferior alveolar nerves and their anomalous relationship with the maxillary artery in the infratemporal fossa. The study was conducted bilaterally on 26 adult cadavers. The variations in the origin and course of the lingual & inferior alveolar nerves were noted. The course of the maxillary artery and its relation to the lingual and inferior alveolar nerves was also recorded. The variations were explained under the following types: a) communication between the lingual and inferior alveolar nerves, b) existence of a pterygospinous ligament/bar overlying/ separating the lingual and inferior alveolar nerves, c) abnormal course/ absence of the chorda tympani nerve and an alternate taste pathway, d) multiple roots of the lingual and inferior alveolar nerves and e) the unusual course of the maxillary artery. Knowledge of these variations would aid the head & neck surgeons in minimizing the compression symptoms and also avoiding postoperative complications.

Key words: Lingual nerve – Inferior alveolar nerve – Maxillary artery – Infratemporal fossa – Variations

INTRODUCTION

The infratemporal fossa is a compact space with various essential contents, situated deep to the mandible, below the greater wing of the sphenoid and behind the body of the maxilla (Standring, 2008). The principal structures of this space, such as the otic ganglion, the chorda tympani nerve (CTN) and the mandibular nerve (MN) and its branches, are well protected by the pterygoid muscles. The single blood supply to this area is accomplished by the maxillary artery (MA), a larger terminal branch of the external carotid artery. The MA usually lies superficial to the branches of the MN (Standring, 2008).

The infratemporal fossa is often the site of pathology or surgical intervention. Since it is a closed location, combined approaches and multidisciplinary planning always need to be considered (Eravci et al., 2016).

Literature is replete with variations in the infratemporal region. It can be in the form of communication between branches of MN or entrapment of nerves by bony bridges. It can also involve the abnormal course and branching pattern of arteries (Erdogmus et al., 2009; Nayak et al., 2008; Potu et al., 2009). However, there are many other variabilities in these structures that are less reported or unreported. The present study is an earnest effort

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to report the common variations of the lingual (LN) and inferior alveolar (IAN) nerves and their anomalous relationship with the MA in the infratemporal fossa.

MATERIALS AND METHODS

The study was carried out using 26 adult cadavers (14 males and 12 females) with a mean age of 64 years wherein a total of 52 infratemporal regions were dissected. The study was carried out on the donated cadavers and in compliance with the ethical guidelines of the institute.

The infratemporal fossa was dissected by removal of the ramus of the mandible. Temporalis was reflected upwards along with the cut coronoid process. The lateral pterygoid was exposed, and the maxillary artery was seen crossing medial to the muscle. The medial pterygoid was present inferior to the maxillary artery. The lower fibers of the lateral pterygoid were removed from the dissection field to visualize underlying neurovascular structures.

Three classical branches of the posterior division of the MN, i.e., LN, IAN and the auriculotemporal nerve (ATN) were identified and exposed carefully. For clear visualization of the variabilities, the nerves were painted yellow using oil paint.

The possible communications between the LN and IAN were noted. These were identified based on the direction of the nerve fibers contained in the communicating branches between the LN and IAN by a teasing examination under the stereomicroscope and immersed water.

The existence of a pterygospinous ligament/bar overlying/separating the LN and IAN were identified. Further, the length of the CTN in the infratemporal fossa (i.e., the distance between the squamotympanic fissure to the point where the CTN joins the LN) was measured and recorded. Variations in the course of the CTN was also noted. Multiple roots of the LN and IAN were also exposed. The variable course of the MA and its relation to the LN and IAN was also observed. The present study was approved by the institutional ethics committee and was conducted on the cadavers that have been voluntarily donated for medical education and research. Informed consent had been taken from the donors during the process of body donation.

RESULTS

Infratemporal regions of 52 specimens (26 right and 26 left) were considered in the present study wherein multiple neurovascular variations were observed. The findings are described below.

Communication between LN and IAN:

A communicating branch from the IAN to the LN was observed in five specimens (Fig. 1a, c).

In all the five specimens observed, the LN was

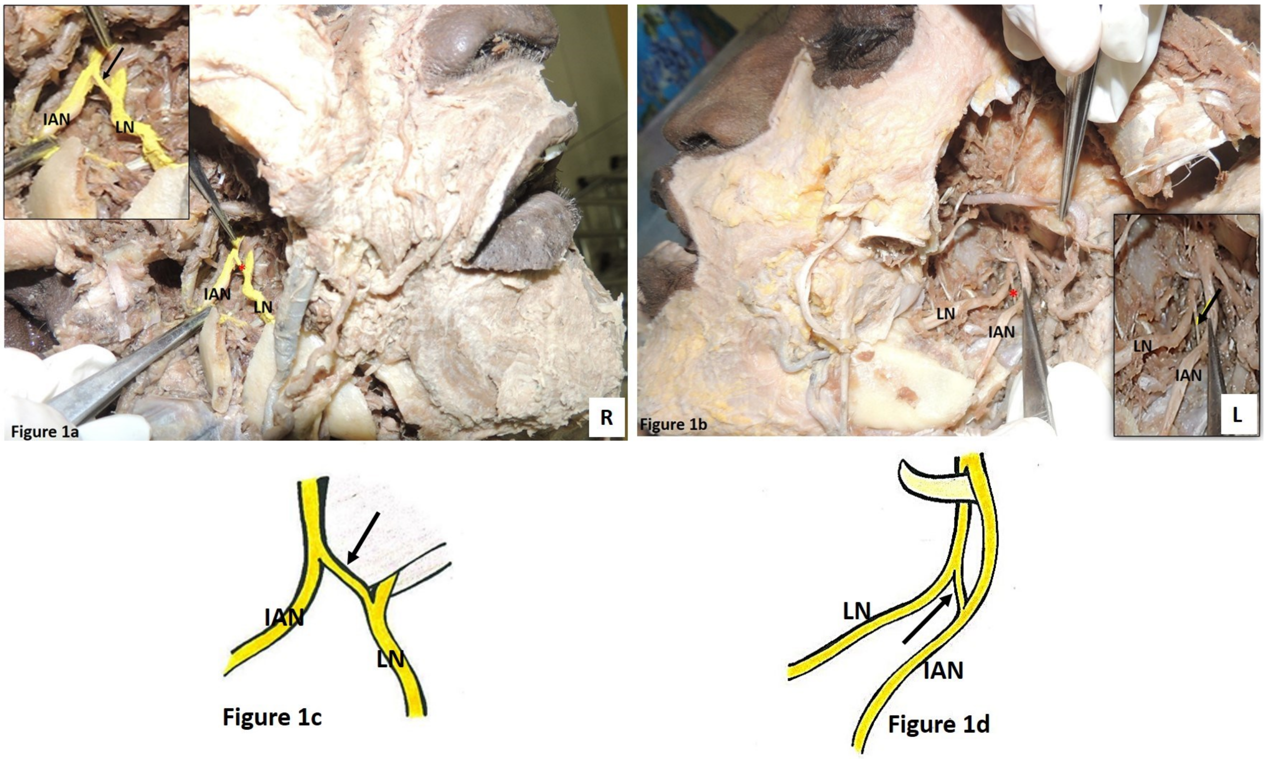

Fig 1. Communication between lingual and inferior alveolar nerves. Fig. **1a** is showing a communicating branch (indicated by * and a black arrow) from the Inferior alveolar nerve (IAN) to the Lingual nerve (LN). Fig. **1b** is showing a communicating branch (indicated by * and a black arrow) from the LN to the IAN. R & L: right and left sides. Figs. **1c** and **1d** are illustrative images representing figs. 1a and 1b respectively. The pale brown and the pale yellow structures in the illustrations 1c and 1d are the pterygospinous ligament and bar, respectively.

relatively slender initially, which after receiving a communicating branch from the IAN, continued as the LN proper.

A communicating branch from the LN to the IAN was also observed in one specimen. The direction of fibers in this communicating branch was from the LN to the IAN (Fig. 1b, d).

No other associated variations were observed in the course and termination of the LN and IAN beyond the level of communication.

The existence of a pterygospinous ligament/ bar and its relationship with the LN and IAN:

The presence of a pterygospinous ligament was also observed in some of the dissected specimens. Partial or complete ossification of the ligament was also identified.

In one of the specimens, the ligament was in the form of a thick fibrous sheath separating the LN from the IAN at the point of their entry into the infratemporal fossa (Fig. 2a, c). Further, in two specimens, the pterygospinous ligament was ossified forming a thick Osseo fibrous plate (pterygospinous bar). This bar was noted to exist between the LN and IAN (Fig. 2b, d).

Abnormal course/ absence of the CTN:

The average length of the CTN in the infratemporal fossa measured about 1.30±0.69 cm with a minimum of 0.70 cm and a maximum of 2.80 cm respectively in 50 out of 52 specimens.

In two specimens, the CTN joining the LN was not defined. The LN instead received a slender communicating branch anteriorly. This communicating branch when further traced was seen to arise from the region of the lateral plate of the pterygoid process (Fig. 3a, b, d, e).

In three specimens, the CTN was seen to emerge deep to the upper head of lateral pterygoid muscle and later joined the LN superficial to the muscle (Fig. 3c, f).

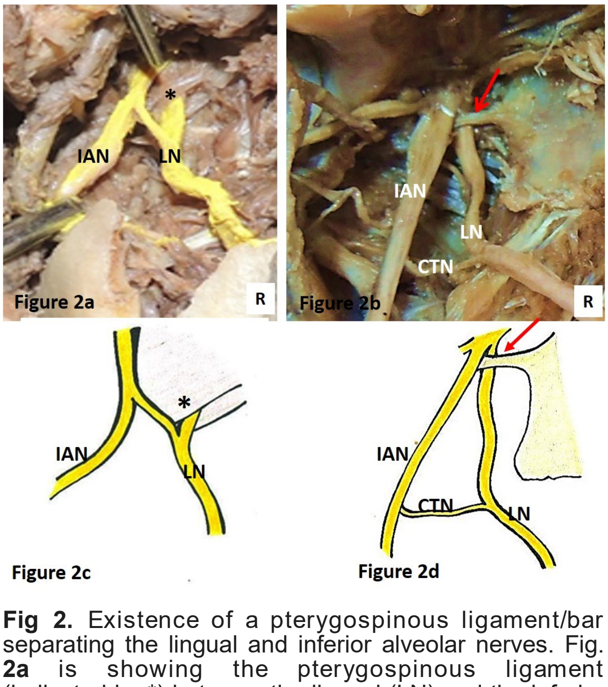

Fig 2. Existence of a pterygospinous ligament/bar separating the lingual and inferior alveolar nerves. Fig. **2a** is showing the pterygospinous ligament (indicated by *) between the lingual (LN) and the inferior alveolar nerves (IAN). The specimen is the same as indicated in Fig. 1a. Fig. **2b** is showing the ossified pterygospinous ligament (pterygospinous bar) (indicated by a red arrow) between the lingual and inferior alveolar nerves. CTN-Chorda tympani nerve. R & L: right and left sides. Figs. **2c** and **2d** are illustrative images representing figs. 2a and 2b, respectively.

Multiple roots of the LN and IAN:

The lingual nerve emerged into the infratemporal fossa in the form of two roots which later united to form the LN proper (Fig. 4a, c). Both the roots were arising separately from the posterior division of the MN which then joined to form a single nerve. The CTN in these cases had a regular course and later combined with the LN. This finding was observed in two specimens.

In yet another specimen, the IAN was seen to arise in the form of three roots which later united to form a single nerve. Out of the three roots, one derived from the LN, the second originated higher above and directly from the posterior division of the MN and the third root arose from the ATN. In this case, the middle meningeal branch of the MA was observed passing between the latter two roots of the IAN (Fig. 4b, d).

Unusual Course of the MA:

The MA exhibited a unique course in the infratemporal fossa. The variations of the MA were grouped into three types.

Type 1: In three specimens, the MA was seen passing deep to the LN and IAN. The CTN joined the LN after coursing deep to the MA (Fig. 5a, d).

Type 2: The MA was coursing through the loop formed by CTN joining the LN. Additionally, the MA was observed to pass deep to the IAN but superficial to the LN. The finding was observed in one specimen (Fig, 5b, e).

Type 3: In one specimen the MA was coursing through the loop formed by the communication between the LN and IAN. The CTN, in this case, was observed to pass deeper and is therefore not identified in the figure (Fig. 5c, f).

DISCUSSION

Communication between LN and IAN:

The connection between the IAN and LN is documented in the literature. It was postulated that the communication might be one of the potential cause for the impaired mandibular anesthesia. Further, the abnormal connection between the nerves may restrict the nerve movement considerably (Nayak et al., 2008). The communication between the inferior alveolar and the buccal nerves have also been identified previously (Kameda, 1952).

In the present study, five cases showed the IAN contributing fibers to the LN. We also observed variability in the direction of the communication, i.e., between the contributing nerve and the recipient's nerve. In one case, the LN was found contributing fibers to the IAN. The finding has not been

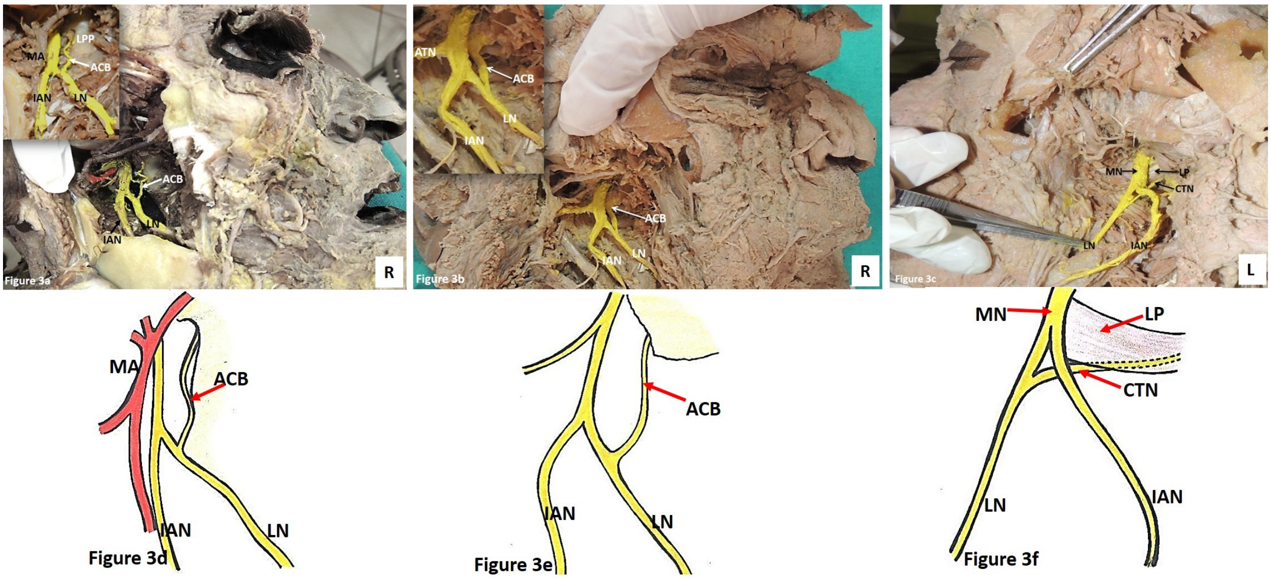

Fig 3. Abnormal course/ absence of the chorda tympani nerve (CTN). Figs. **3a** and **3b** show the Lingual nerve (LN) receiving a slender communicating branch anteriorly (ACB) from the region of the lateral plate of the pterygoid process (LPP). The chorda tympani nerve is not found in this case. IAN- Inferior alveolar nerve, MA- Maxillary artery, R & L: right and left sides. Fig. **3c** is showing the mandibular nerve lying (MN) superficial to the upper head of lateral pterygoid muscle (LP). The CTN emerges deep into the LP and later joins the lingual nerve (LN). MN-Mandibular nerve (Posterior division), IAN- Inferior alveolar nerve, R & L: right and left sides. Figs. **3d**, **3e** and **3f** are illustrative images representing figs. 3a, 3b and 3c, respectively.

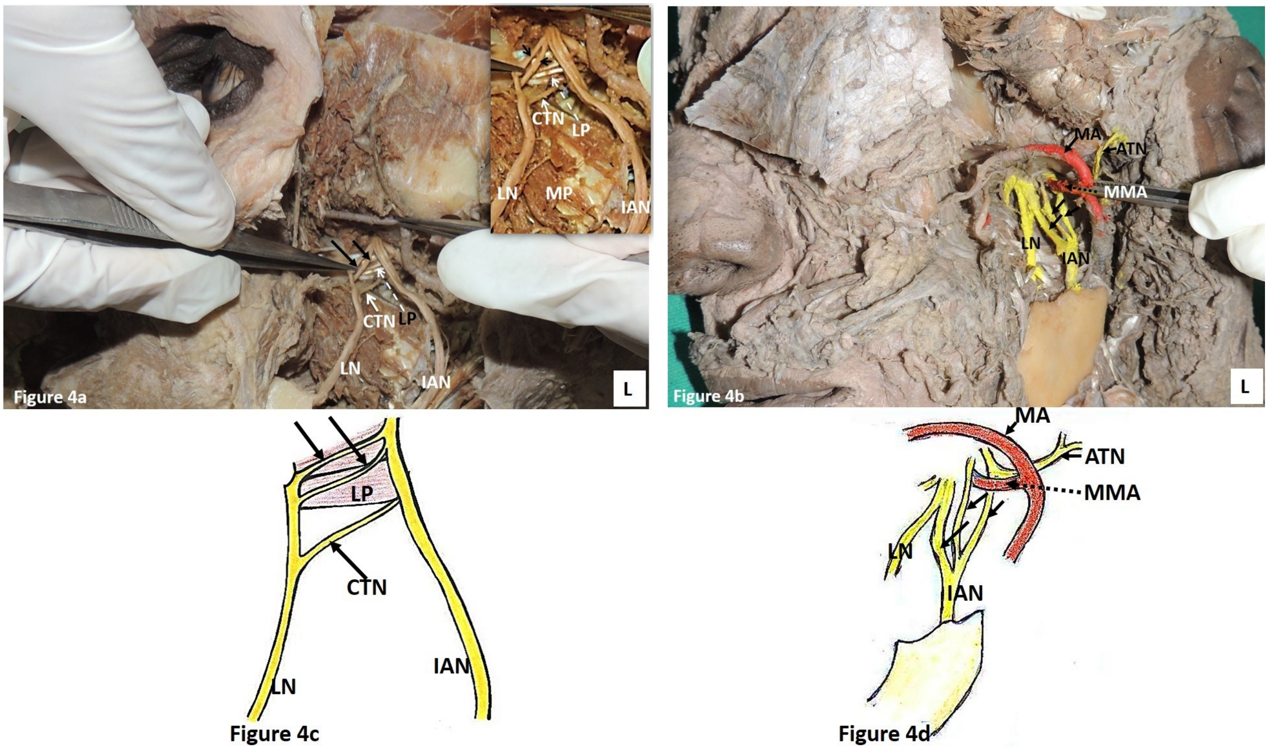

Fig 4. Multiple roots of the lingual and inferior alveolar nerves. Fig. **4a** is showing the two roots of the lingual nerve (LN) (indicated by black arrows) emerging separately from the posterior division of the mandibular nerve and later uniting to form a single nerve. In the same specimen, the chorda tympani nerve (CTN) is observed to join the Lingual nerve (LN) after passing deep to the lateral pterygoid muscle (LP). IAN- Inferior alveolar nerve. Fig. **4b** is showing the inferior alveolar nerve (IAN) arising in the form of three roots (indicated by black arrows) which later united to form a single nerve. Out of the three roots, one derived from the lingual nerve (LN), the second originated higher above and directly from the posterior division of the mandibular nerve and the third root arose from the auriculotemporal nerve (ATN). In this case, the middle meningeal branch (MMA) of the maxillary artery (MA) is observed to pass between the latter two roots of the inferior alveolar nerve. L: Left side. Figs. **4c** and **4d** are illustrative images representing figs. 4a and 4b, respectively.

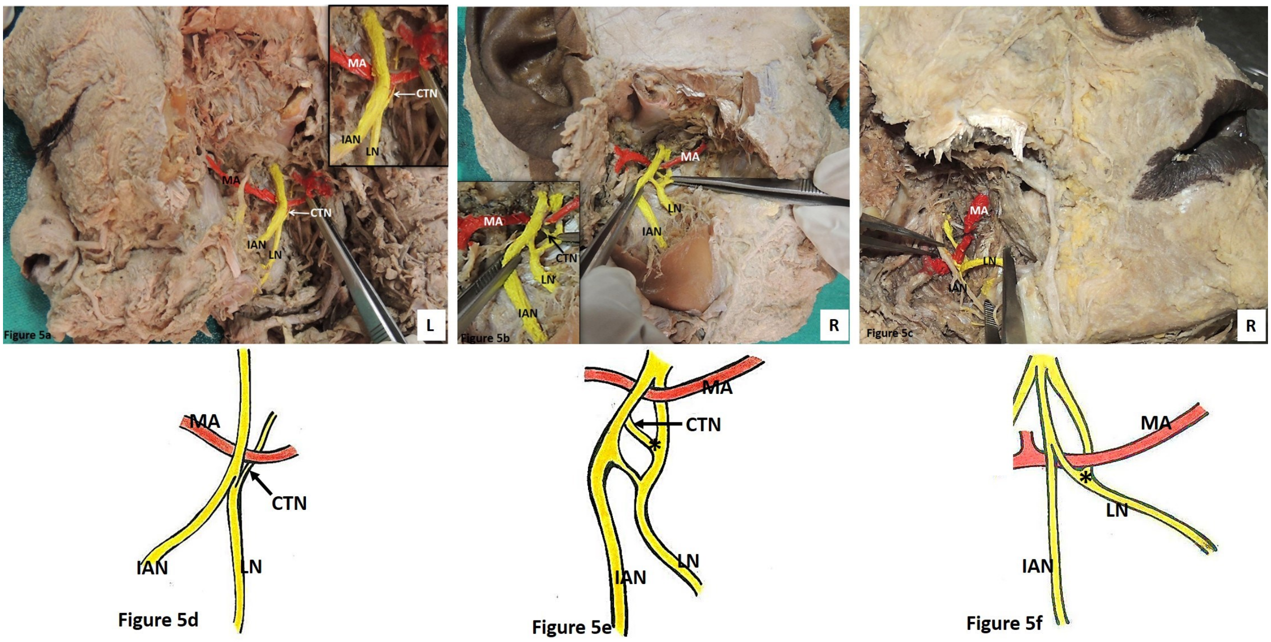

Fig 5. Unusual course of the maxillary artery. Fig. **5a** is showing the maxillary artery (MA) running deep to the lingual (LN) and inferior alveolar (IAN) nerves. The chorda tympani nerve (CTN) is observed joining the LN after coursing deep to the MA. Fig. **5b** is showing the maxillary artery (MA) coursing through the loop (indicated by *) formed by the chorda tympani nerve (CTN) joining the lingual nerve (LN). In this case, the MA is observed to pass deep to the IAN but superficial to the LN. Fig. **5c** is showing the maxillary artery (MA) coursing through the loop (indicated by *) formed by the communication between the lingual nerve (LN) and inferior alveolar nerve (IAN). R & L: right and left sides. Figs. **5d**, **5e** and **5f** are illustrative images representing figs. 5a, 5b and 5c, respectively.

discussed previously.

The existence of a pterygospinous ligament/ bar and its relationship with the LN and IAN:

Several ligaments (such as pterygospinous, interclinoid, caroticoclinoid, and pterygoalar ligaments) are related to the sphenoid bone. Ossification of these ligaments may lead to many complications (Peuker et al., 2001).

The pterygospinous ligament is encountered in the infratemporal fossa. Civinini first described it in 1835 (Tebo, 1968), and it was reported by Peuker et al. in 2001.

The present study also reported the existence of this ligament. It was in the form of a connective tissue sheath enveloping the LN, thereby separating it from the IAN.

The pteryospinous ligament can undergo ossification and form a pterygospinous bar. The presence of an extensive pterygospinous bar is documented in the skulls of herbivores, rodent, carnivorous animals and mature monkeys (Von Ludinghausen et al., 2006). The pterygospinous bar passing through fibers of the LN dividing it into anterior and posterior divisions was previously reported by Erdogmus et al. (2009). The incidence of the pterygospinous bar has also been previously reported in dried skulls in the Korean population with the purpose of improving the effectiveness of the surgical and anesthetic procedures (Ryu et al., 2016).

The ossified pterygospinous ligament may cause compression of the LN, leading to numbness and pain in its distribution with associated speech impairment. Complete or incomplete pterygospinous bar when present may affect the exit of MN from the foramen ovale or its branches as it enters the infratemporal fossa. It may also compress some structures, including otic ganglion, middle meningeal artery and vein, tympanic nerve, and even the medial and lateral pterygoid muscles. These structures when compressed may produce many clinical symptoms like pain during chewing and may trigger trigeminal neuralgia (Krmpotic-Nemanic et al., 1999).

In the present case, a well-defined bony spicule (pterygospinous bar) was seen to separate the descending branches of the posterior division of the MN during its exit through the foramen ovale. This bar was identified between the LN and IAN. The CTN, in this case, was not related to the pterygospinous bar and therefore was spared from compression. Contrary to this, other authors have previously reported abnormal taste sensation in the anterior two-thirds of the tongue due to the compression of the CTN by the anomalous bar of bone (Das et al., 2007).

Abnormal course/ absence of the CTN:

The extra-cranial course of the CTN is sparsely described in the existing literature. The unusual course of the CTN in the infratemporal fossa is less discussed. The cases such as the absence of CTN and an unusual extra-temporal course of the CTN deep to the upper head of lateral pterygoid muscle are reported in the present study. However, Proctor and Nager (1982) stated that the origin of the CTN might vary considerably from 1mm distal to 11mm proximal to the stylomastoid foramen. They also observed another temporal origin of the CTN in 2% of cases of their study, wherein it traveled in its separate canaliculus parallel to the facial canal.

In the present study, the LN received a communicating branch from the region of the lateral plate of the pterygoid process. We assume that this communicating branch may be arising from the greater petrosal nerve and joining the LN. The CTN joining the LN posteriorly was not observed in this case. It indicates an alternate taste pathway in the absence of the CTN.

The taste sensations from the anterior two-thirds of the tongue would have probably been conveyed to the greater petrosal nerve via the LN owing to the absence of the CTN as observed in the present study. Furthermore, the secretomotor fibers, i.e., the parasympathetic fibers to the submandibular ganglion would have also been carried via the greater petrosal nerve and later provided to the LN.

The facial nerve may be somewhat variable in its anatomical course through the temporal bone. Owing to this, the endotemporal branching pattern of the facial nerve may also be variable (Proctor and Nager, 1982). This further justifies the absence of the CTN and the compensation provided by the greater petrosal nerve. It, however, needs to be also studied.

In yet another scenario, the CTN after emerging from the petro-tympanic fissure initially coursed deep to the upper head of the lateral pterygoid muscle and later joined the LN superficial to it. The deep fibers of the lateral pterygoid muscle separating the CTN from the LN could lead to nerve compression. These observations are unusual and have not been reported elsewhere.

Multiple roots of the LN and IAN:

The existence of two roots of the LN has previously been reported by Daimi et al. (2011). In their case, the posterior root of the LN arose directly from the MN, while the anterior root emerged as a branch of the common trunk descending from the MN. The other branch of the common trunk continued as the IAN.

In the present study, both the roots of the LN were arising separately from the posterior division of the MN, which further united to form a single nerve. This observation was unique and was not reported previously.

Various authors have also studied multiple roots of the IAN. In a study conducted by Roy et al. (2002) on 80 infratemporal fossae, one-half showed the presence of two roots of IAN. They also reported that the second part of MA passed through the loop formed by the two roots of IAN. A similar variation has been described by Babu et al. (2011), Khan et al. (2010) and Sharma et al. (2011). According to a case reported by Pai et al. (2010), the IAN presented three roots, one each from the posterior division of MN, LN, and ATN. The MA passed in between the loop formed by the roots emerging from the posterior division of MN and ATN. A similar case was reported by Pretterklieber et al. (1991), in which the MA pierced the IAN and there was a communication between the IAN and LN. Roy et al. (2002) reported two roots of the IAN and the mylohyoid nerve originating from the deep root. Quadros et al. (2014) reported a case in which the IAN was formed by three roots, one from LN and two from the ATN which encircled the middle meningeal artery.

In the present study too the IAN presented three roots. In this case, one root arose from the LN, the second from the posterior division of the MN and the third root from the ATN. The middle meningeal branch of the MA was identified passing between the last two roots of the IAN.

Embryologically, the MN and its branches develop from the neural crest cells in the cephalic region, which migrate ventrally through the ectomesenchyme of the mandibular arch. It is made possible by the multiple cell-matrix interactions (Bronner -Fraser, 1993), contact repulsion and chemorepulsion (Sanes et al., 2000; Tannahill et al., 1997). F-spondin and T-cadherin liberated from the caudal somites are believed to inhibit the neural crest cell migration (Debby-Brafman et al., 1999; Ranscht and Bronner-Fraser, 1991). It may be responsible for the nerve variations. As the IAN is a mixed nerve, separate developmental pathways for the motor and sensory fibers may result in the formation of multiple roots that may later reunite to form a single trunk (Pai et al., 2010).

These anatomical variations could be the reason for certain trigeminal pain conditions and should be considered during the dental, oncological and reconstructive surgeries of the infratemporal fossa and for adequate anesthesia (Roy et al., 2002). The compression of the IAN by the pulsating MA and middle meningeal artery may lead to pain and numbness without any neurological symptoms. Middle meningeal artery compressed by the roots of IAN encircling it may lead to reduced arterial supply to the middle cranial fossa (Quadros et al.,2014).

Unusual Course of the MA:

In the present study, we came across a case wherein where the MA was running deep to the LN and IAN. The CTN was related deep to the MA initially and later joined the LN. This finding is unusual. The other rare variation found in the present study was the MA coursing through the loop between the LN and the CTN. In this case, the MA was observed to pass deep to the IAN but superficial to the LN. This finding was unique and was rarely reported in the existing literature.

In yet another case, the MA was found to course through the loop formed by the communication between the IAN and the LN in the present study.

Similar observations were also made by Sandoval et al. (2009). In a case report by Daimi et al. (2011), the MA was observed to course between the two roots of the LN. Therein the communication of the CTN was not found. Unusual course of the MA through the IAN (Babu et al., 2011) and through the loop of ATN (Bhat et al., 2016) has also been reported. Ortug and Moriggl (1991) also reported a case in which the MA pierced the IAN. The LN was not involved in this case. Anil et al. (2003) reported an MA coursing through the two roots of the IAN. The intramuscular course of the MA through temporalis muscle has also been identified previously (Patil et al., 2013).

The MA develops from a vascular network in the infratemporal region, provided by the pterygoid mass of myoblasts. The stapedial artery feeds the network initially, followed by the external carotid artery in later development. During this phase, the vascular network disappears typically, except for those that are destined to develop into the MA. However, some of the vessels may be persistent and may be present between the loops of the variant nerves, thereby resulting in the variable course of the MA and its branches (Roy et al., 2002; Hogg et al.,1972).

The abnormal course of MA in the infratemporal fossa may be lead to complications during the administration of local anesthetic to the IAN. It may further lead to the formation of hematoma and exert a soft pressure in surrounding structures such as LN and the IAN leading to sensory alterations. It may be considered one of the differential diagnoses of facial pain, hyperalgesia, and allodynia (Sandoval et al., 2009). The artery passing through the nerve loop during increased blood flow may irritate the surrounding nerves, leading to tingling and numbness in their area of distribution.

Conclusion

The infratemporal fossa is a small but complex region in the base of the skull and therefore entails the neuro- and head and neck surgeons to have detailed knowledge of the topography and contents of the area. A thorough anatomic understanding of the possible variations as is reported in the present study should become obligatory to manage the benign or malignant lesions in the infratemporal fossa. It will also help them in minimizing the compression symptoms and also avoiding postoperative complications. The present study has made an earnest effort to report the common variations of the lingual, inferior alveolar and chorda tympani nerves, and their anomalous relationship with the maxillary artery in the infratemporal fossa.

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