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The extracranial course of the facial nerve and bony anatomical landmarks for localization of the facial nerve trunk during parotidectomies

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SUMMARY

Paralysis of the facial nerve is a common complication during the surgical removal of parotid gland tumors (parotidectomies). This may be due to the close relationship of the tumor and the facial nerve (along its extracranial course). This study aimed to explore the extracranial course of the facial nerve in terms of branching patterns, bony anatomical landmarks and variations. The sample comprised of 40 facial nerve specimens. The parameters identified and recorded were facial nerve trunk division, branching patterns and variations in terms of connections, course and branching. The parameters were classified and compared according to sex and laterality. Bifurcation of the facial nerve trunk occurred in 90% of cases, whilst trifurcation occurred in only 10%. The cases of trifurcation displayed variations. The frequency of each type of branching pattern was: Type I =7.5%, Type II =12.5%, Type III =25%, Type IV =15%, Type V =27.5% and Type VI =12.5%. The six types were further categorized into three subtypes based on the origin of the buccal branch. The distance from the facial nerve trunk to bony anatomical landmarks was measured viz. mastoid process, angle of the mandible and external auditory canal. Only the distance to the angle of the mandible displayed significant differences according to sex (p-value <0.001) and laterality (p- value =0.002). All three landmarks displayed good-excellent reliability (ICC values ranged from 0.82 to 0.95) with regard to bony anatomical landmarks for the localization of the facial nerve trunk. The present study proposes the use of the three subtypes in conjunction with the classification system. Anatomical knowledge of the extracranial course of the facial nerve and its relation to bony anatomical landmarks are of importance to surgeons during procedures such as parotidectomies.

Key words: Facial nerve – Extracranial course – Branching patterns – Trunk division – Bony anatomical landmarks – Facial nerve trunk

INTRODUCTION

The extracranial course of the facial nerve and its variable branching patterns, particularly at its terminal branches, have been the subject of many studies since the nineteenth century (Martínez Pascual et al., 2018). The facial nerve begins its

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extracranial course by exiting the stylomastoid foramen, located at the base of the skull (Standring and Gray, 2005; Sinnatamby, 2011; Moore et al., 2014). Standard anatomical textbooks describe the nerve at this point as the main trunk of the facial nerve (Moore et al., 2014). The main trunk then gives rise to a posterior auricular nerve, nerve to the stylohyoid and nerve to the posterior belly of the digastric before proceeding anteriorly towards the posteromedial surface of the parotid gland (Standring and Gray, 2005; Sinnatamby, 2011; Moore et al., 2014). The nerve then divides into the upper temporofacial and lower cervicofacial divisions slightly behind the retromandibular vein, before entering the parotid gland or within it (Standring and Gray, 2005; Sinnatamby, 2011). Further branching forms the parotid plexus within the gland (Standring and Gray, 2005; Sinnatamby, 2011). This plexus has a plexiform arrangement and lies superficial to the retromandibular vein and external carotid artery (Sinnatamby, 2011). The parotid plexus then forms the five terminal branches of the facial nerve: temporal, zygomatic, buccal, marginal mandibular and cervical (Moore et al., 2014). Each terminal branch is named for the region it supplies, and each supply specific muscles of facial expression (Moore et al., 2014). The terminal branches leave the parotid gland at its anteromedial surface and proceed to innervate their respective muscles of facial expression (Standring and Gray, 2005). Any injury or damage to the facial nerve could lead to paralysis of the facial muscles, resulting in a loss of facial expression (Pather and Osman, 2006).

Many variations in the extracranial course of the facial nerve have been noted in the literature. Anatomists have previously proposed numerous classification systems in an attempt to better organize and understand the variable pattern of the facial nerve extracranial course (Kwak et al., 2004; Weerapant et al., 2010; Khaliq et al., 2016; Rana et al., 2017; Martínez Pascual et al., 2018). Studies by Kwak et al. (2004), Weerapant et al. (2010), Khaliq et al. (2016), Rana et al. (2017) and Martínez Pascual et al. (2018) have identified between four to twelve different types of branching patterns displayed by the facial nerve. Previous studies described the number of terminal branches and trunks, buccal branch origin and connections, which were utilized in order to develop these classification systems (Kwak et al., 2004; Weerapant et al., 2010; Khaliq et al., 2016; Rana et al., 2017; Martínez Pascual et al., 2018). Davis et al. (1956, cited by Weerapant et al., 2010) studied 350 cervicofacial halves and was the first to categorize the facial nerve into six types of branching patterns within the parotid gland according to the presence of anastomosis between its divisions and branches. Most studies have utilized the six-type classification system proposed by Davis et al. (1956, cited by Rana et al., 2017) to classify the branching patterns they observed (Weerapant et al., 2010; Khaliq et al., 2016; Rana et al., 2017). However, this classification system overlooks the significance of the variability in the number and course of the terminal branches, as well as the variability in buccal branch origin and number of connections (Martínez Pascual et al., 2018).

Recent studies by Rana et al. (2017) and Martínez Pascual et al. (2018) illustrated that the branching pattern of the facial nerve, particularly at the terminal branches, varies greatly and has been found to be independent of sex and laterality. Few studies, however, have compared the branching pattern of the facial nerve according to sex and laterality (Rana et al., 2017; Martínez Pascual et al., 2018). The variable branching patterns of the facial nerve may also be different on either side of the same individual (Weerapant et al., 2010; Rana et al., 2017). Kirici et al. (2011) and Martínez Pascual et al. (2018) identified variable numbers of each terminal branch. The facial nerve has also shown great variation with regards to number of trunks, number of divisions (viz. bifurcation, trifurcation and no branching) and buccal branch origin being observed (Kwak et al., 2004; Khaliq et al., 2016; Rana et al., 2017; Martínez Pascual et al., 2018).

Many bony and soft tissue landmarks have been proposed to aid surgeons in the early identification and detection of the facial nerve trunk. Bony landmarks, however, have been advocated as the most suitable, due to their reliable and rigid anatomical location (Greyling et al., 2007). Bony landmarks are also easily palpable (preoperatively or during the course of the surgery), which makes them ideal for location of the facial nerve trunk, as no unnecessary dissection would be required (Zhong and Ashwell, 2015). However, few studies have focused on all bony anatomical landmarks such as the angle of the mandible, styloid process, mastoid process and external auditory canal, specifically their distances from the facial nerve trunk and their reliability as landmarks. Pather and Osman (2006) and Zhong and Ashwell (2015) identified the distance from these landmarks to the facial nerve trunk as being different on either side or in the different sexes, while other studies disagree, identifying no significant differences with regards to sex or laterality (Pather and Osman, 2006; Greyling et al., 2007; Zhong and Ashwell, 2015).

Parotid gland tumors and parotid neoplasms account for around 80% of all salivary gland tumors. Parotid neoplasms are the most diverse and complex group of tumors originating in the head and neck region. Most of these tumors occur in adults, affecting both sides of the face equally, but they do have a slightly higher incidence in females and individuals over 65 years of age (Pather and Osman, 2006).

Facial nerve paralysis is a widely reported possible complication of parotidectomies, as parotid surgery requires the excision of the parotid gland tumor. During this surgical procedure, the facial nerve is one of the most crucial structures that will be encountered, chiefly because the tumor and nerve are usually closely related. Any injury or damage to the facial nerve could lead to paralysis of the facial muscles, which would result in a loss of facial expression (negatively influencing the patient), as well as potential medico-legal implications for the operating surgeon. Thus, it is vital for the surgeon to avoid injuring the facial nerve during the surgical removal of parotid gland tumors (Pather and Osman, 2006).

The variable nature of the facial nerve anatomy, in terms of number of trunks, divisions (bifurcation, trifurcation, etc.) and branching patterns, increases the chance of facial palsy after surgery if the surgeon is unaware of, or does not have sufficient knowledge of, these anatomical variations (Martínez Pascual et al., 2018). Surgeons operating in the region of the facial nerve must have an understanding of the diversity of the facial nerve's branching pattern (Rana et al., 2017). Proper identification and precise detection of the facial nerve trunk is also crucial. Thus, knowledge of the key anatomical landmarks that can be used for the identification and detection of the facial nerve trunk is vital for effective and safe surgical procedures in the region of the parotid gland and facial nerve (Pather and Osman, 2006). A parotidectomy can be a difficult operation, but becomes less demanding for the surgeon if the facial nerve trunk is identified (Saha et al., 2013).

This study aimed to explore the extracranial course of the facial nerve in terms of branching patterns, bony anatomical landmarks and variations. In addition, the study aimed to compare these parameters according to sex and laterality.

MATERIALS AND METHODS

Twenty embalmed adult cadaveric heads (11 male and 9 female), were obtained from the Discipline of Clinical Anatomy, School of Laboratory Medicine and Medical Sciences, College of Health Sciences at the University of Kwazulu-Natal in order to dissect the extracranial course of the facial nerve bilaterally (n=40 facial nerve specimens). Full ethical approval was granted by the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu-Natal (BE364/19). The mean age of the cadavers was 80 years old, ranging between 57-101 years of age.

The dissection procedure was followed utilizing the method by Detton and Tank (2017). The skin over the forehead and lower face was reflected from the midline laterally (after the appropriate skin incisions were made). Care was taken to leave the connective tissue and muscles intact and not reflected, in order to avoid accidental reflection of or damage to the facial nerve branches. Superficial fascia was removed on the lateral aspect of the face in order to identify the masseter muscle, in the region of the angle of the mandible. Next, the parotid duct was identified by further removal of superficial fascia on the lateral surface of the masseter, and was utilized to locate the buccal branch of the facial nerve. The buccal branch was found running parallel to the parotid duct, superiorly or inferiorly. It was defined and traced back to the parotid gland using blunt dissection and, by removing the parotid gland tissue piece by piece, its connection to the parotid plexus and the other terminal branches of the facial nerve was identified. Initial identification of the parotid duct is crucial in order to identify the buccal branch and, subsequently, the other terminal branches. The terminal branches of the facial nerve (temporal, zygomatic, marginal mandibular and cervical) were traced and defined peripherally, from the parotid plexus until their termination at the facial muscles. The branches of the parotid plexus were traced posteriorly and deeply, beneath the earlobe, in order to identify the trunk of the facial nerve. The dissection was continued posteriorly until the facial nerve trunk's emergence from the stylomastoid foramen was identified. The course of the facial nerve and its branching patterns and variations within the parotid gland were recorded and classified according to the six-type classification system proposed by Davis et al. (1956, cited by Rana et al., 2017). The classification system was as follows:

"Type I: There was no anastomosis between terminal branches of facial nerve."

"Type II: There was an anastomotic association between branches of temporofacial division."

"Type III: Only a single anastomosis was present between temporofacial and cervicofacial division."

"Type IV: It was a combination of type II & III."

"Type V: Two anastomotic rami were present, from cervicofacial division to intercede with branches of temporofacial division."

"Type VI: A plexiform arrangement, in which a mandibular branch was sending a twig to join any branch of temporofacial division."

Next, the skin was further reflected laterally, together with the auricle of the ear, in order to identify the mastoid process and external auditory canal. The junction between the bony and cartilaginous external auditory canal (anterior to the ear), the tip of the styloid process, the tip of the mastoid process and tip of the angle of the mandible were palpated and pinned. The facial nerve trunk was also pinned. The shortest distance (in mm) from the facial nerve trunk to these bony anatomical landmarks was measured utilizing vernier calipers (Fig. 1). Each measurement (i.e., from the trunk to each landmark) was repeated three times in order to determine the intra-observer error. The measurements from 10 specimens (25% of the sample) were repeated by another observer (second ob-

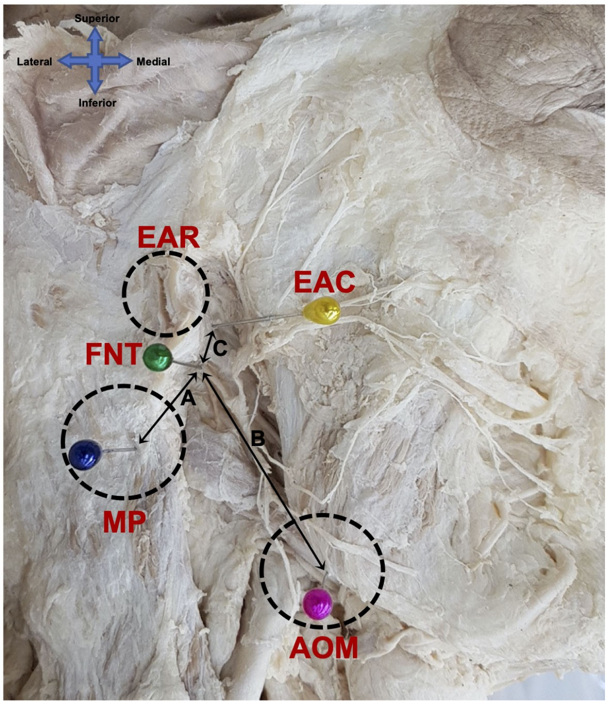

Fig 1. Distance from the facial nerve trunk to bony anatomical landmarks. *Key*: FNT (Green pin) = Facial nerve trunk, MP (Blue pin) = Mastoid process, AOM (Pink pin) = Angle of the mandible, EAC (Yellow pin) = External auditory canal, **A** = Distance from the trunk to the mastoid process, **B** = Distance from the trunk to the angle of the mandible, **C** = Distance from the trunk to the external auditory canal.

server) in order to determine the inter-observer error. This ensured the reliability and validity of the measurements.

Statistical Analysis

In this study, categorical variables such as sex were summarized as percentages or proportions. Morphological differences of the facial nerve were compared according to sex and laterality using Fisher's exact test or Chi-squared test, as appropriate. Morphometrical data pertaining to each bony anatomical landmark of interest were analyzed and compared according to sex and laterality using t-tests. Intra-observer error and inter-observer error were calculated and represented as intraclass correlation coefficients (ICC values) in order to determine the reliability of the data. All analyses were conducted using statistical software R, with a level of significance kept at $p<0.05$.

RESULTS

Twenty embalmed adult cadaveric heads (11 male and 9 female) were utilized and dissected bilaterally in the study. The study sample consisted of 40 facial nerve specimens (20 left and 20 right). The facial nerve always originated from the stylomastoid foramen before bifurcating/trifurcating and eventually giving rise to five terminal branches.

Facial Nerve Trunk Division

Bifurcation of the facial nerve trunk into the temporofacial and cervicofacial divisions, according to the standard anatomical definition, occurred in 36/40 specimens (90% of cases) overall [Right: 17/20 (85%); Left 19/20 (95%); Male: 20/22 (90.91%); Female: 16/18 (88.89%)] (Table 1) (Fig. 2A).

Trifurcation of the facial nerve trunk occurred in 4/40 specimens (10% of cases) overall [Right: 3/20 (15%); Left 1/20 (5%); Male: 2/22 (9.09%); Female: 2/18 (11.11%)] (Table 1) (Fig. 2B).

There were no cases of quadrification of the faci-

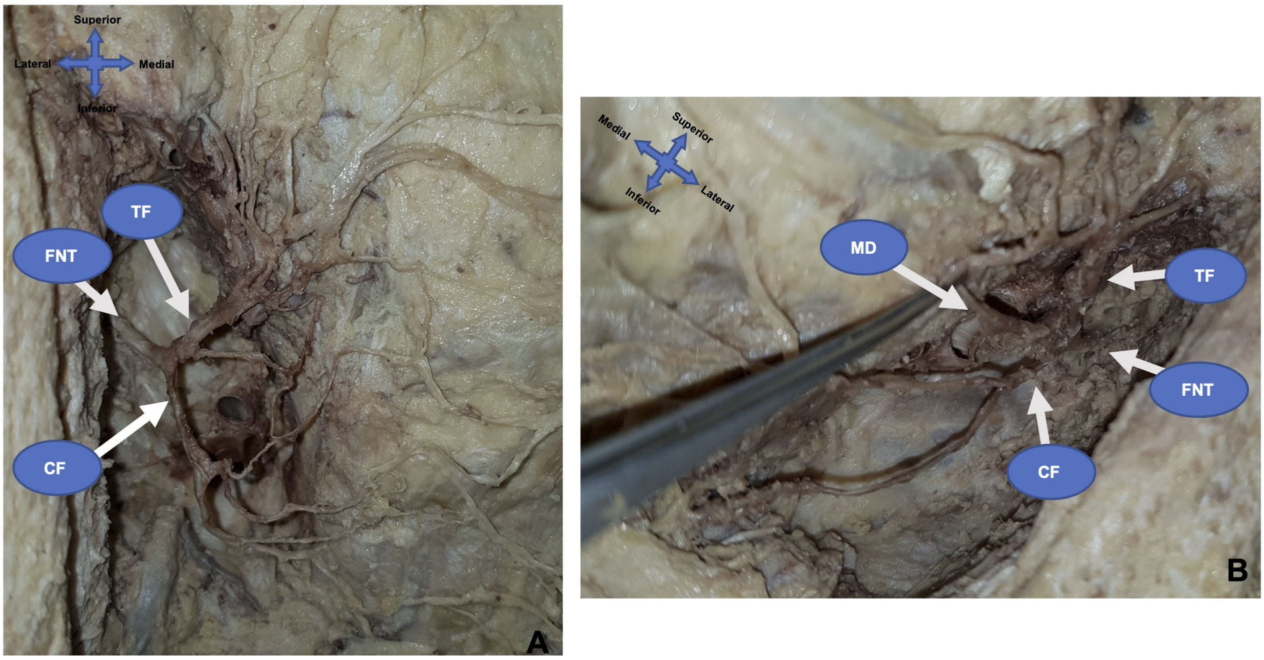

Fig 2. Facial Nerve Trunk Division (A) Bifurcation and (B) Trifurcation. Key: FNT = Facial nerve trunk, TF = Temporofacial division, CF = Cervicofacial division, MD = Middle Division.

Table 1. Facial nerve trunk division

	Bifurcation n (%)	Trifurcation n (%)	Total n (%)	P-value
Right	17 (85)	3 (15)	20 (100)	0.263
Left	19 (95)	1 (5)	20 (100)	
Total	**36 (90)**	**4 (10)**	**40 (100)**	
Male	20 (90.91)	2 (9.09)	22 (100)	1
Female	16 (88.89)	2 (11.11)	18 (100)	
Total	**36 (90)**	**4 (10)**	**40 (100)**	

*Cases of single trunk and quadrification were not observed.

al nerve trunk and no branching (in which a single trunk divides into the plexiform arrangement and the five terminal branches) observed in this study (Table 1).

The cases of trifurcation identified in the present study displayed variations. All four cases resulted in the facial nerve trunk trifurcating into the temporofacial division, cervicofacial division and a third division, between the two latter divisions. However, in three cases the third division gave rise to a buccal branch, and in one case the third division gave rise to two marginal mandibular branches, all of which eventually anastomosed with the other terminal branches (Fig. 2B).

No statistically significant differences according to sex (p-value =1) or laterality (p- value =0.263) were identified (Table 1). Therefore, the facial nerve trunk division was found to be independent of sex and laterality.

Branching Patterns

The branching patterns of the facial nerve from the 40 specimens were classified into six types based on the presence of anastomosis between its branches and divisions (Table 2).

Type I occurred in 3/40 specimens (7.5% of cases) overall [Right: 2/20 (10%); Left 1/20 (5%); Male: 2/22 (9.09%); Female: 1/18 (5.56%)] (Figs. 3A & 3B).

Type II occurred in 5/40 specimens (12.5% of cases) overall [Right: 4/20 (20%); Left 1/20 (5%); Male: 4/22 (18.18%); Female: 1/18 (5.56%)] (Figs. 3C & 3D).

Type III occurred in 10/40 specimens (25% of cases) overall [Right: 3/20 (15%); Left 7/20 (35%);

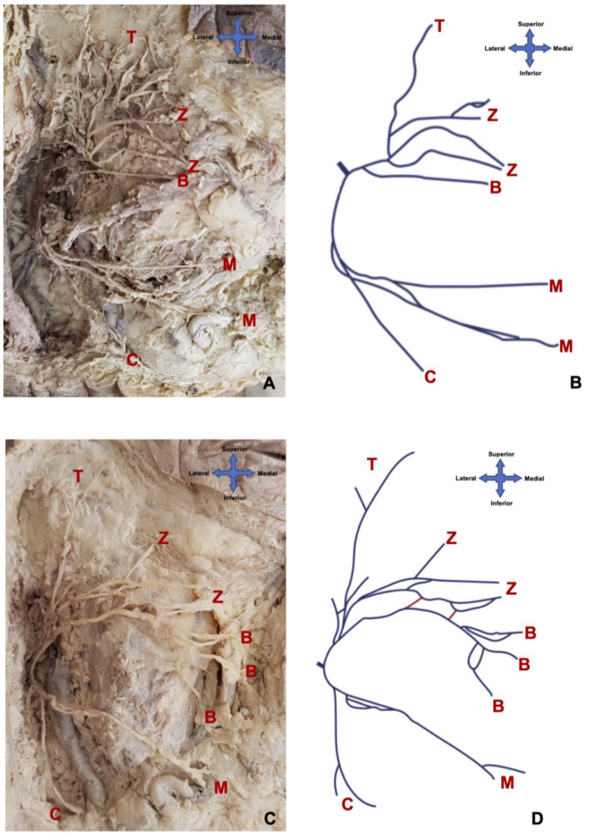

Fig 3. (A) Branching pattern Type I, comprising of no connections between the terminal branches. **(B)** Illustration of Type I. **(C)** Branching pattern Type II, comprising of two connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division) and **(D)** Illustration of Type II. Key: T = Temporal branches, Z = Zygomatic branches, B = Buccal branches, M = Marginal mandibular branches, C = Cervical branches, Red line = Anastomotic associations (Connections).

Male: 6/22 (27.27%); Female: 4/18 (22.22%)] (Figs. 4A & 4B).

Type IV occurred in 6/40 specimens (15% of cases) overall [Right: 4/20 (20%); Left 2/20 (10%); Male: 3/22 (13.64%); Female: 3/18 (16.67%)] (Figs. 4C & 4D).

Type V occurred in 11/40 specimens (27.5% of cases) overall [Right: 5/20 (25%); Left 6/20 (30%); Male: 5/22 (22.73%); Female: 6/18 (33.33%)] (Figs. 5A & 5B).

Type VI occurred in 5/40 specimens (12.5% of cases) overall [Right: 2/20 (10%); Left 3/20 (15%);

Table 2. Classification of the variable branching patterns of the facial nerve

	Type I n (%)	Type II n (%)	Type III n (%)	Type IV n (%)	Type V n (%)	Type VI n (%)	Total n (%)	p-value
Right	2 (10%)	4 (20%)	3 (15%)	4 (20%)	5 (25%)	2 (10%)	20 (100%)	0.095
Left	1 (5%)	1 (5%)	7 (35%)	2 (10%)	6 (30%)	3 (15%)	20 (100%)	
Total	**3 (7.5%)**	**5 (12.5%)**	**10 (25%)**	**6 (15%)**	**11 (27.5%)**	**5 (12.5%)**	**40 (100%)**	
Male	2 (9.09%)	4 (18.18%)	6 (27.27%)	3 (13.64%)	5 (22.73%)	2 (9.09%)	22 (100%)	0.441
Female	1 (5.56%)	1 (5.56%)	4 (22.22%)	3 (16.67%)	6 (33.33%)	3 (16.67%)	18 (100%)	
Total	**3 (7.5%)**	**5 (12.5%)**	**10 (25%)**	**6 (15%)**	**11 (27.5%)**	**5 (12.5%)**	**40 (100%)**	

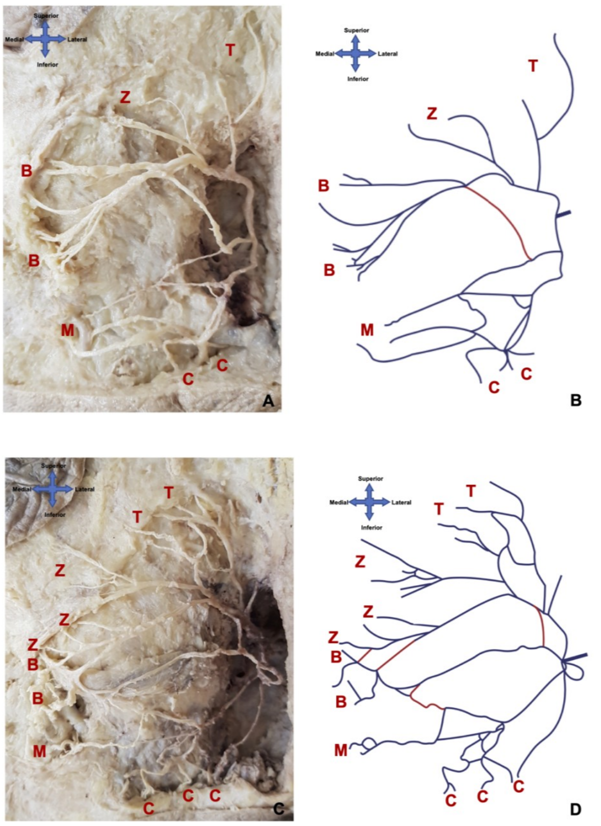

Fig 4. (**A**) Branching pattern Type III, comprising of a single connection between the buccal branch (temporofacial division) and marginal mandibular branch (cervicofacial division). (**B**) Illustration of Type III. (**C**) Branching pattern Type IV, comprising of three connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division) and a single connection between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) and (**D**) Illustration of Type IV and connections. Key: T = Temporal branches, Z = Zygomatic branches, B = Buccal branches, M = Marginal mandibular branches, C = Cervical branches, Red line = Anastomotic associations (Connections).

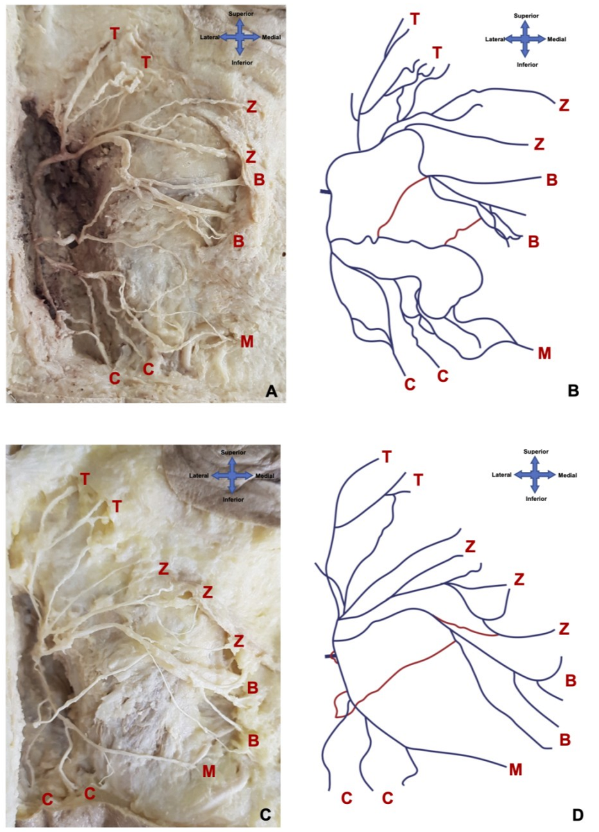

Fig 5. (**A**) Branching pattern Type V, comprising of two connections between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division). (**B**) Illustration of Type V. (**C**) Branching pattern Type VI, comprising of a single connection between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division) and two connections between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) and (**D**) Illustration of Type VI. Key: T = Temporal branches, Z = Zygomatic branches, B = Buccal branches, M = Marginal mandibular branches, C = Cervical branches, Red line = Anastomotic associations (Connections).

Male: 2/22 (9.09%); Female: 3/18 (16.67%)] (Figs. 5C & 5D).

A symmetrical branching pattern was identified in six cadavers (30% of cases). No statistically significant differences according to sex (p-value =0.441) or laterality (p- value =0.095) were identified (Table 2). Therefore, the branching pattern of the facial nerve was found to be independent of sex and laterality.

Subtypes

The six types were further divided into three subtypes based on the buccal branch origin, as this study found that the buccal branch displayed variable origin. In subtype A, the buccal branch originated from the temporofacial division; in subtype B, the buccal branch originated from the cervicofacial division, and in subtype C the buccal branch originated from both divisions (Table 3).

Connections

The present study classified the branching patterns of the facial nerve into six types, based on the presence of anastomosis (connections) between individual terminal branches and divisions. However, numerous cases of a higher number of connections, more than those specified by the classification system, between individual terminal branches and divisions were identified and recorded [13/40 specimens (32.5% of cases)]:

Two cases comprised of a single connection between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division), and two connections between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) (Type VI) (Figs. 5C & 5D).

Two cases comprised of a single connection between the zygomatic branch (temporofacial divi-

Table 3. Classification of the subtypes of the variable branching patterns of the facial nerve

Type	I n (%)			II n (%)			III n (%)			IV n (%)			V n (%)			VI n (%)		
***Subtype**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Right	1 (5)	-	1 (5)	4 (20)	-	-	-	2 (10)	1 (5)	3 (15)	-	1 (5)	2 (10)	2 (10)	1 (5)	2 (10)	-	-
Left	-	1 (5)	-	-	-	1 (5)	4 (20)	2 (10)	1 (5)	2 (10)	-	-	2 (10)	3 (15)	1 (5)	2 (10)	-	1 (5)
Total	**1 (2.5)**	**1 (2.5)**	**1 (2.5)**	**4 (10)**	**-**	**1 (2.5)**	**4 (10)**	**4 (10)**	**2 (5)**	**5 (12.5)**	**-**	**1 (2.5)**	**4 (10)**	**5 (12.5)**	**2 (5)**	**4 (10)**	**-**	**1 (2.5)**
Male	-	1 (4.6)	1 (4.6)	3 (13.6)	-	1 (4.6)	2 (9.1)	4 (18.2)	-	3 (13.6)	-	-	2 (9.1)	3 (13.6)	-	1 (4.6)	-	1 (4.6)
Female	1 (5.6)	-	-	1 (5.6)	-	-	2 (11.1)	-	2 (11.1)	2 (11.1)	-	1 (5.6)	2 (11.1)	2 (11.1)	2 (11.1)	3 (16.7)	-	-
Total	**1 (2.5)**	**1 (2.5)**	**1 (2.5)**	**4 (10)**	**-**	**1 (2.5)**	**4 (10)**	**4 (10)**	**2 (5)**	**5 (12.5)**	**-**	**1 (2.5)**	**4 (10)**	**5 (12.5)**	**2 (5)**	**4 (10)**	**-**	**1 (2.5)**

*Subtype A: Buccal branch originated from the temperofacial division. *Subtype B: Buccal branch originated from the cervicofacial division. *Subtype C: Buccal branch originated from the temperofacial and cervicofacial divisions.

sion) & buccal branch (temporofacial division), and three connections between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) (Type VI).

One case comprised of a two connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division), and three connections between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) (Type VI).

One case comprised of three connections between the zygomatic branch (temporofacial division) & buccal branch (cervicofacial division) only (Type V).

One case comprised of a single connection between the temporal branch (temporofacial division) & zygomatic branch (temporofacial division), and two connections between the zygomatic branch (temporofacial division) & buccal branch (cervicofacial division) (Type V).

Three cases comprised of three connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division), and a single connection between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) (Type IV) (Figs. 4C & 4D).

One case comprised of two connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division), and a single connection between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division) (Type IV).

Two cases comprised of two connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division) only (Type II) (Figs. 3C & 3D).

Overall

Nine cases comprised of one to three connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division), and one to three connections between the buccal branch (temporofacial division) & marginal mandibular branch (cervicofacial division), in various arrangements (Figs. 4C, 4D, 5C & 5D).

One case comprised of three connections between the zygomatic branch (temporofacial division) & buccal branch (cervicofacial division) only.

One case comprised of a single connection between the temporal branch (temporofacial division) & zygomatic branch (temporofacial division), and two connections between the zygomatic branch (temporofacial division) & buccal branch (cervicofacial division).

Two cases comprised of two connections between the zygomatic branch (temporofacial division) & buccal branch (temporofacial division) only (Figs. 3C & 3D).

Variations in the course and branching of the facial nerve

Buccal Branch

In one case, the buccal branch traversed the parotid duct by descending diagonally, as opposed to its normal parallel relation to the parotid duct.

In one case, two buccal branches were identified, one originating from the temporofacial division (superior) and one originating from the cervicofacial division (inferior). An anastomotic association was formed between the two.

Marginal Mandibular Branch

In one case, the marginal mandibular branches originated from the distal end of the buccal branch before descending to the body of the mandible and innervating the respective muscles.

In one case, one marginal mandibular branch proceeded anterosuperiorly towards the buccal branch, formed an anastomotic association with the buccal branch and then descended to the body of the mandible, accompanying the other marginal mandibular branches.

In one case, marginal mandibular branches origi-

Table 4. Distance from the facial nerve trunk to each bony anatomical landmark and comparison of the differences according to sex and laterality

	Mastoid Process					Angle of the Mandible					External Auditory Canal				
	Min (mm)	Mean (mm)	S.D. (mm)	Max (mm)	p-value	Min (mm)	Mean (mm)	S.D. (mm)	Max (mm)	p-value	Min (mm)	Mean (mm)	S.D. (mm)	Max (mm)	p-value
Overall	9.5	20.4	7.0	36.9		26.0	44.0	7.6	55.9		7.3	13.5	2.9	20.2	
Right	12.5	20.8	6.4	32.2	0.212	26.6	45.1	7.3	55.9	0.002	8.9	13.2	2.8	20.2	0.068
Left	9.5	20.0	7.6	36.9		26.0	42.9	7.8	54.4		7.3	13.7	2.9	19.9	
Male	12.3	20.6	7.1	36.9	0.399	39.0	47.5	4.7	55.9	<0.001	7.3	13.7	3.1	20.2	0.069
Female	9.5	20.1	6.9	34.5		26.0	39.7	8.3	54.9		8.9	13.2	2.6	19.9	

*$n_{overall}$ = 40, *n_{right} = 20 & n_{left} = 20 , n_{male} = 22 & n_{female} = 18

nated from the temporofacial division of the facial nerve (Fig. 6), as opposed to the originating from the cervicofacial division according to the standard anatomical definition.

Bony Anatomical Landmarks

The mean distance from the facial nerve trunk to the a) mastoid process was 20.4 mm, b) angle of the mandible was 44.0 mm and c) external auditory canal was found to be 13.5 mm (Table 4). The styloid process was situated very deeply, making it difficult to palpate. Therefore, measurements from the facial nerve trunk to the styloid process could not be taken reliably.

Significant differences in the measured parameters were identified in the distance from the facial nerve trunk to the angle of the mandible, in terms of sex (p-value <0.001) and laterality (p-value =0.002) (Table 4). The distance was found to be longer on the right side (mean =45.1 mm), than the left side (mean =42.9 mm), and longer in male specimens (mean =47.5 mm), than female specimens (mean =39.7 mm) (Table 4).

Intra-observer Error

Measurements from the facial nerve trunk to the a) mastoid process yielded an ICC value of 1 on the right and 1 on the left, b) angle of the mandible yielded an ICC value of 1 on the right and 1 on the left, and c) external auditory canal yielded an ICC value of 0.98 on the right and 0.99 on the left. All ICC values indicated an excellent reliability.

Inter-observer error

Measurements, between the observer and a second observer, from the facial nerve trunk to the a) mastoid process yielded an ICC value of 0.95 on the right and 0.83 on the left, indicating excellent and good reliability respectively, b) angle of the mandible yielded an ICC value of 0.82 on the right and 0.82 on the left, indicating good reliability, and c) external auditory canal yielded an ICC value of 0.91 on the right and 0.95 on the left, indicating excellent reliability. Thus, the present study found that the mastoid process, angle of the mandible and external auditory canal were all reliable bony anatomical landmarks for the localization of the facial nerve trunk.

DISCUSSION

Facial Nerve Trunk Division

Martínez Pascual et al. (2018) only identified cases of bifurcation of the facial nerve trunk. Rana et al. (2017) identified cases of bifurcation (95%), trifurcation (3%) and no branching (single trunk) (2%). Khaliq et al. (2016) identified cases of no branching (single trunk) (91.4%) and bifurcation (8.57%). Whereas, Kwak et al. (2004) identified cases of bifurcation (86.7%) and trifurcation (13.3%) only. The present study also identified cases of bifurcation (90% of cases) and trifurcation (10% of cases) only, frequencies observed were in agreement with that of previous studies (Kwak et al., 2004; Rana et al., 2017) (Table 5).

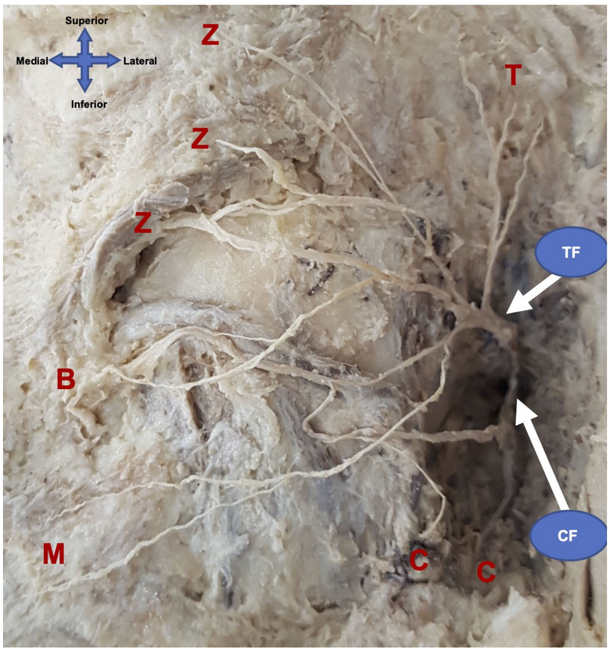

Fig 6. Variation showing the marginal mandibular branches originating from the temporofacial division. Key: T = Temporal branches, Z = Zygomatic branches, B = Buccal branches, M = Marginal mandibular branches, C = Cervical branches, TF = Temporofacial division, CF = Cervicofacial division.

Table 5. Comparison of facial nerve trunk division in previous studies

Study	No branching (Single Trunk) (%)	Bifurcation (%)	Trifurcation (%)	Quadrification (%)
Kwak et al. (2004)	-	86.7	13.3	-
Khaliq et al. (2016)	91.4	8.57	-	-
Rana et al. (2017)	2	95	3	-
Martínez Pascual et al. (2018)	-	100	-	-
Present Study	-	90	10	-

Variations were observed in the four cases (10%) of trifurcation, identified in the present study: a) three resulted in the facial nerve trunk trifurcating into the temporofacial division, cervicofacial division and a third division, between the two latter divisions, that gave rise to a buccal branch, which anastomosed with the other terminal branches; and b) one resulted in the facial nerve trunk trifurcating into the temporofacial division, cervicofacial division and a third division, between the two latter divisions, that gave rise to two marginal mandibular branches, which anastomosed with the other terminal branches. Kwak et al. (2004) also identified cases of trifurcation in which the middle division originated between the upper and lower divisions before connecting in various patterns with the other two main divisions.

Branching Patterns

Kwak et al. (2004) classified the branching pattern of the facial nerve based on the buccal branch origin. Weerapant et al. (2010) and Rana et al. (2017) used a classification system proposed by Davis et al. (1956, cited by Rana et al., 2017) to record the variable branching patterns they encountered. Davis et al. (1956, cited by Weerapant et al., 2010) studied 350 cervicofacial halves and categorized six types of facial nerve branching patterns within the parotid gland according to the presence of anastomosis between its divisions and branches. Martínez Pascual et al. (2018) proposed a new twelve type classification system based on connections, buccal branch origin and number of facial nerve trunks, whilst also taking into consideration previously proposed classification systems and the study's results.

The Davis et al. (1956, cited by Rana et al., 2017) six-type classification system is commonly used to classify the variable branching patterns (Weerapant et al., 2010; Khaliq et al., 2016; Rana et al., 2017). Therefore, the present study utilized this classification system as well. However, this classification system overlooks the significance of the variability in the number and course of the terminal branches, as well as the variability in buccal branch origin and number of connections as found in the present study. This is consistent with the recent study by Martínez Pascual et al. (2018).

The present study proposes the use of the three subtypes, based on origin of the buccal branch, in conjunction with the Davis et al. (1956, cited by Rana et al., 2017) six-type classification system to classify the variable branching patterns of the facial nerve. Furthermore, the present study noted that variations exist in the number of connections displayed by the Davis et al. (1956, cited by Rana et al., 2017) classification system. The present study identified numerous cases that comprised a higher number of connections than those specified by the Davis et al. classification system. Previous studies have not noted these variations. Therefore, the number of connections is not necessarily limited to those stated in the classification system.

According to Rana et al. (2017), the patterns observed were independent of age, sex, ancestry and laterality. Weerapant et al. (2010) identified more complex patterns than those described by Davis et al.'s (1956, cited by Rana et al., 2017) six-type classification system, and a symmetrical branching pattern was identified in only 30% of cases. Martínez Pascual et al. (2018) found no statistically significant differences between sex (p-value =0.583) or laterality (p-value =0.379) in the branching patterns. The present study also identified a symmetrical branching pattern in 30% of cases, as well as no statistically significant differences according to sex (p-value =0.441) or laterality (p-value =0.095) (Table 2). Hence, the study also found the branching pattern of the facial nerve to be independent of sex and laterality.

Type I occurred in 7.5% of cases in the present study, which is similar to the study by Rana et al (2017). However, Khaliq et al. (2016) recorded a much higher frequency of Type I (34.2% of cases). Type I is of particular clinical significance because this pattern possesses no anastomoses among its branches. Thus, damage to any branch would result in paralysis of the respective facial muscles, since there is no alternate pathway (via anastomotic associations/connections) to innervate these muscles. Type V (27.5% of cases) was the most frequent pattern observed in the present study, whilst Type I (7.5% of cases) was the least frequent pattern observed which corroborates previous studies (Weerapant et al., 2010). The present study's second most prevalent type was Type III (25% of cases). Similar frequencies of Type III have been observed in numerous studies

Table 6. Comparison of the frequency (%) of each type

Studies	Type I	Type II	Type III	Type IV	Type V	Type VI
Weerapant et al. (2010)	1	10	20	18	29	21
Khaliq et al. (2016)	34.2	14.2	25.7	11.4	8.5	5.7
Rana et al. (2017)	9	39	20	25	6	1
Present Study	7.5	12.5	25	15	27.5	12.5

(Weerapant et al., 2010; Khaliq et al., 2016; Rana et al., 2017) (Table 6).

Variations in the course and branching of the facial nerve

In this study, a single case in which the marginal mandibular branches originated from the temporofacial division of the facial nerve was observed (female specimen on the left). This finding is rare, as this was observed in only one case in a study by Kirici et al. (2011). In addition, other variations in the course and branching of the facial nerve were identified, such as: a) a single case in which the buccal branch traversed the parotid duct diagonally; b) a single case in which two buccal branches were identified, one originating from the temporofacial division (superior) and one originating from the cervicofacial division (inferior); c) a single case in which the marginal mandibular branches originated from the distal end of the buccal branch before descending to the body of the mandible; and d) one case in which one marginal mandibular branch proceeded antero-superiorly towards the buccal branch, formed an anastomotic association with the buccal branch and then descended to the body of the mandible. These variations have not been documented in the literature.

Bony Anatomical Landmarks

Mastoid Process

Zhong and Ashwell (2015) recorded the distance from the facial nerve trunk to the mastoid process and illustrated significant differences in sexes (p-value =0.004) with a longer distance observed in males (Table 7). However, Zhong and Ashwell (2015) recorded no significant differences between the different sides (p-value =0.358). Greyling et al. (2007) concluded that there were no significant differences, in the distance, in terms of sex, side, length or weight. The present study identified no significant differences in terms of this distance, according to sex (p-value =0.399) or laterality (p-value =0.212) (Table 4). Farahvash et al. (2013) identified the distance from the facial nerve trunk to the tip of the mastoid process as the most appropriate index to specify the trunk, recording the distance as 11.81mm on the right and 11.62mm on the left (Table 7). The present study found the mastoid process deep to the insertion of the sternocleidomastoid muscle. Thus, it could only be identified by palpating over the muscle. This is in agreement with Saha et al. (2013), which states that since the mastoid process is located deep to the insertion of the sternocleidomastoid, it is mainly a palpatory landmark. The ICC values of 0.95 on the right and 0.83 on the left, between the measurements taken by the observer and second observer in the present study, indicates that it displayed a good-excellent reliability as a landmark for localization of the facial nerve trunk.

Angle of the Mandible

Pather and Osman (2006) recorded significant differences in the distance from the facial nerve trunk to the angle of the mandible, between the left

Table 7. Comparison of the mean distance (mm) between the facial nerve trunk and bony anatomical landmarks according to sex and laterality

Study	Mastoid Process				Angle of the Mandible				External Auditory canal			
	Right	Left	Male	Female	Right	Left	Male	Female	Right	Left	Male	Female
Pather and Osman (2006)	-	-	-	-	39.7	36.5	40.8	35.1	12.8	14.0	13.1	13.7
Greyling et al. (2007)	9.35	9.18	-	-	-	-	-	-	-	-	-	-
Farahvash et al. (2013)	11.81	11.62	-	-	-	-	-	-	-	-	-	-
Zhong and Ashwell (2015)	-	-	14.8	13.5	-	-	-	-	-	-	15.2	14.8
Present Study	20.8	20.0	20.6	20.1	45.1	42.9	47.5	39.7	13.2	13.7	13.7	13.2

and right sides of the face (p-value =0.03) and between the different sexes (p-value =0.00): the distance was found to be longer on the right side and in males (Table 7). The present study also identified significant differences in this distance in terms of laterality (p-value =0.002) and sex (p-value <0.001), being longer on the right side and in males (Table 4). Pather and Osman (2006) found the angle of the mandible to be within 38.1mm (25.3 - 48.69mm) from facial nerve trunk, whilst the present study found it within 44.0mm (26.0-55.9mm) of the facial nerve trunk (Table 4). Differences between the findings can be attributed to the differences in the bony structure of males and females, with males having a more prominent and robust lower jaw (Pather and Osman, 2006). The angle of the mandible was found to be the most easily identifiable landmark in the present study with little to no dissection being required in order to identify this landmark by palpation. The ICC values of 0.82 on the right and 0.82 on the left, between the measurements taken by the observer and second observer in the present study, indicates that it displayed good reliability as a landmark for localization of the facial nerve trunk.

External Auditory Canal

Pather and Osman (2006) and Zhong and Ashwell (2015) identified no significant differences, in the distance from the facial nerve trunk to the external auditory canal, in terms of sex or laterality. The present study concurs with these findings, identifying no significant differences in this distance, according to sex (p-value = 0.069) or laterality (p-value = 0.068) (Table 4). Pather and Osman (2006) found the external auditory canal to be within 13.4mm (7.3 - 21.9mm) of the facial nerve trunk, whilst the present study found it within 13.5mm (7.3 - 20.2mm) of the facial nerve trunk (Table 4). The present study found that the bony-cartilaginous junction could only be identified with a degree of dissection. The ICC values of 0.91 on the right and 0.95 on the left, between the measurements taken by the observer and second observer in the present study, indicates that it displayed excellent reliability as a landmark for localization of the facial nerve trunk.

Styloid Process

Pather and Osman (2006) noted that the use of the styloid process as a landmark for identification of the facial nerve trunk was unsafe. This was due to its being situated deeper than the facial nerve trunk, leading to the possibility of damaging the trunk before the landmark is identified (Pather and Osman, 2006). The styloid process is also absent in 30% of specimens, as well as being small and shielded by its sheath in another 20% of specimens (Pather and Osman, 2006). This could account for the present study's difficulty in palpating this landmark and obtaining reliable measurements.

Few studies have reviewed and compared the reliability of these three bony anatomical landmarks, according to sex and laterality (Table 7). Significant differences noted between sexes can be attributed to males generally having a larger and more robust skull than females (Pather and Osman, 2006; Zhong and Ashwell, 2015). Significant differences noted between the different sides could simply be attributed to slight differences in skeletal structure on either side of the face. Previous studies have identified several other landmarks (bony and soft tissue) as reliable for localization of the facial nerve trunk. Pather and Osman (2006) concluded that the transverse process of the axis was one of the most reliable and safe landmarks, since it could be easily palpated and did not require complex or deep dissection. Greyling et al. (2007) proposed the use of the most central point of the transverse process of the atlas vertebrae. Saha et al. (2013) identified the posterior belly of the digastric as the best landmark to use initially and, in cases of difficulty, concluded that it could be supplemented with the tragal pointer and tympanomastoid suture line. Zhong and Ashwell (2015) also recommended the posterior belly of the digastric muscle as a surgical landmark, as well as the use of more consistent bony landmarks when necessary. Bony landmarks have been advocated as the most suitable due to their reliable and rigid anatomical location (Greyling et al., 2007). The present study utilized the mastoid process, angle of the mandible and external auditory canal as landmarks for localization of the facial nerve trunk, because of the lack of literature pertaining to these landmarks. Furthermore, they are also easily palpable (preoperatively or during the course of the surgery), which makes them ideal for location of the facial nerve trunk, as no unnecessary dissection would be required (Zhong and Ashwell, 2015).

Conclusion

The facial nerve was observed to have many variations along its extracranial course, particularly its branching pattern, including buccal branch origin and number of connections, and type of facial nerve trunk division. Surgeons operating in the region of the facial nerve must be aware of the diversity in the facial nerve's branching pattern and variations, in order to avoid injuring the nerve (Rana et al., 2017). Few studies have reviewed and compared the reliability of all three bony anatomical landmarks, comparing according to sex only and laterality only. This study concludes that all three of these landmarks can be reliable bony anatomical landmarks for the localization of the facial nerve trunk. However, differences in terms of sex and laterality should also be taken into consideration when utilizing these landmarks. Surgeons should also utilize these landmarks in conjunction with other landmarks (bony or soft tissue) in order to effectively locate the facial nerve trunk. Future studies could look at the relations of the facial nerve along its extracranial course or focus on identifying new bony or soft tissue anatomical landmarks for localization of the facial nerve trunk.

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