EXTRATEMPORAL FACIAL NERVE ANATOMICAL VARIATIONS IN CADAVERS AT KENYATTA NATIONAL HOSPITAL MORTUARY

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A Dissertation submitted for examination in partial fulfillment of the requirements for award of the degree of Master of Dental Surgery in Oral and Maxillofacial Surgery of the University of Nairobi.

2015

DECLARATION

I hereby declare that this dissertation is my original work and that it has not been submitted to any other university or elsewhere.

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DEDICATION

I dedicate this study to my wife Dr Gasheri Thuku and my son Jayden Mutahi for their unwavering patience, support and sacrifice they have shown throughout my postgraduate course. I also wish to dedicate this work to my parents for their never ending support and prayers.

ACKNOWLEDGMENTS

I specially appreciate my supervisors Dr. F. Butt, Prof. S. Guthua and Prof. M. Chindia for the guidance and mentorship throughout the study. I also acknowledge Dr Philip Maseghe of the department of Human Anatomy, University of Nairobi, for the additional supervision and guidance provided. I am also deeply indebted to the staff of Kenyatta National Hospital (KNH) farewell home and in particular Dr. Walong, of the department of Human Pathology, for their facilitation in dissection and data collection.

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List of abbreviations

CN	Cranial nerve
EAM	External auditory meatus.
FN	Facial nerve
KNH	Kenyatta National Hospital
PBDM	Posterior belly of the digastric muscle.
SMA	Stylomastoid artery
SPSS	Statistical package for social sciences.
TMJ	Temporomandibular joint.
TMS	Tympanomastoid suture .
TP	Tragal pointer.
UNES	University of Nairobi Enterprise and Services Limited.
UON	University of Nairobi

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ABSTRACT

BACKGROUND**:** The facial nerve (FN) is the seventh cranial nerve (CN). It is a mixed nerve with motor supply to the facial muscles being most crucial. It exhibits diversity in its course, dimensions and anatomic relations especially in the extratemporal part. An intimate knowledge of its anatomy is critical to avoid its inadvertent injury during rhytidectomy, parotidectomy, maxillofacial trauma surgery and ideally in any surgery of the head and neck region.

METHODOLOGY: Dissection of fresh cadavers in Kenyatta National hospital mortuary during post mortem examination.

STUDY OBJECTIVE**:** To establish the anatomic relationships and variability of the extratemporal FN trunk and its branches with emphasis on the intraparotid connections between the divisions and relations to various surgical landmarks.

STUDY DESIGN**:** This was a descriptive cross-sectional study design using quantitative techniques of data collection on cadavers. The data includes morphometry of the FN as well as the various patterns of its distribution.

STUDY AREA AND POPULATION: The study was conducted at the Kenyatta National Hospital (KNH) mortuary. The study population included cadavers that were presented for post mortem examination. A special chart was used to collect data.

DATA ANALYSIS AND PRESENTATION**:** Data were coded and analyzed using the SPSS version 18.0 software. Descriptive analysis was done and presented using frequency diagrams, tables and graphs. Statistical tests included the Mann Whitney U, Wilcoxon signed rank,

Spearman and Pearson coefficient frequency tests. The results were presented in the form of tables and figures.

RESULTS: Twenty fresh cadavers were dissected left and right sides among which 12(60%) were males while 8(40%) were females (40FNs). The frequency of the various branching patterns using the Davis et al.1956 classification was as follows: types I 10(25%), II-9(22.5%), III- 7(17.5%), IV 6 (15%), V 2 (5%) and IV 6 (15%). The FN was noted to bifurcated in 32 (80%) and trifurcated in 8(20%) cases. However there was no significant difference in the branching patterns (p=0.509) and furcation types (p=0.414) between the right and left sides and between the genders. Regarding the morphometric data of the FN, the length of the FN was 16.14mm (+/- 3.28),the distance from the FN trunk to the tragar pointer (TP) was 9.87mm(SD+/-2.41), tympanomastoid suture(TMS) 5.81mm(+/- 1.28), external auditory meatus (EAM) 15.64mm(+/- 2.74), posterior belly of the digastrics muscle (PBDM) 8.09mm(+/-1.78), styloid process 16.48mm(+/- 5.47), temporomandibular joint(TMJ) 22.55mm(+/-1.99) and angle of the mandible 37.98(+/- 4.45). The styloid process was missing in 9 (22.9%) of the hemifacial dissections.

The Mann Whitney U test did not elicit a statistically significant difference of the right side length of the trunk between genders (p=.238) and also the independent t test of means of the landmarks did not show any significant difference between the male and female cases. There was a positive correlation (Pearson’s correlation test) between the right side and the left side branching patterns (p=.002), length of the FN trunk(p=.000), TP(p=.003), TMS(p=.000), EAM(p=.000), PBDM(p=.003), the styloid process(p=.004) and angle of the mandible(p=.001) which was significant.

CONCLUSION: The current study establishes variations of anatomical patterns of the extracranial FN in a Kenyan population. It shows that type I (Davis et al. 1956 classification) branching pattern as the commonest. The TMS and PBDM were the most accurate landmarks in FN trunk identification.

RECOMMENDATIONS: The study strongly shows that the TMS and PBDM can be used as landmarks for the identification of the FN during surgery.

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

The facial nerve (FN) is the seventh cranial nerve (CN) which is a mixed nerve carrying sensory fibres including special sensory (taste) and somatic (general), somatic (branchial) motor and visceral (parasympathetic) motor components. It also carries proprioceptive fibers from the muscles it innervates [1]. Voluntary control of the branchial branch of the FN is initiated by supranuclear inputs arising from the cerebral cortex projecting to the facial nucleus of the pontine tegmentum via the corticobulbar tracts. Spontaneous facial muscle movements are centrally transmitted via the extrapyramidal system. The FN nuclei contain the cell bodies of its lower motor neurons. These cell bodies receive supranuclear inputs via synapse formation with axons traveling through both the pyramidal and extrapyramidal systems. These postsynaptic lower motor neurons confluence around the abducens nucleus and form the facial colliculus at the floor of the fourth ventricle. The motor branch of the FN exits the brainstem at the cerebellopontine angle, where it is joined by the nervus intermedius. It then travels about 15.8 mm from the cerebellopontine angle before entering the temporal bone [2].

The parasympathetic component of the FN is composed of visceral motor fibers whose cell bodies are scattered within the pontine tegmentum and collectively known as the superior salivatory nucleus. Cell bodies mediating the general sensory function of the FN reside in the general sensory trigeminal nucleus[2]. Topographically the nerve can be divided into three parts: intracranial, intratemporal and extracranial.

Both the FN proper and the intermedius nerve emerge from the brainstem at the cerebellopontine angle at the caudal border of the pons, between the abducens and the vestibulocochlear nerves [3]. The intracranial portion is a 23 - 24 mm segment from the cerebellopontine angle to the internal auditory canal [4].

The FN traverses the petrous part of the temporal bone from the internal auditory meatus to the stylomastoid foramen. As it exits through the stylomastoid foramen in the base of skull, the extracranial portion of the facial nerve may be located 21+/-3.1 mm below the skin. Here, it immediately gives branches off the main trunk to the auricular muscles, the posterior belly of the digastric and the stylohyoid muscles [5]. It supplies sensory (vagal) fibers to parts of the external auditory canal and some areas of the auricle, including the lobules. The nerve then courses ventrally and at the posterior edge of the parotid gland it splits into the upper and lower divisions [6]. Within the parotid gland, there is further branching with multiple individual variations [7-10] .The upper (temporofacial) division of the FN gives off the temporal, zygomatic and buccal branches whereas the lower (cervicofacial) division gives off the marginal mandibular and cervical branches [7].It is the most frequently injured of all the CNs, causing paralysis of the muscles of facial expression. Although it is a mixed nerve, the motor component is the most important due to the significance of facial palsy[7,9,11,12].

The anatomic pathways followed by the FN and its relations are very important and carry great significance for anatomists, surgeons and clinicians in order to make accurate diagnosis and effective surgical intervention [6]. The FN trunk being dissected and manipulated between the exit from the cranial base through the stylomastoid foramen and its furcation is a crucial stage in a number of craniofacial, otological, plastic and neurosurgical procedures [13].The iatrogenic injury of this part of the FN is very common [7, 9, 11, 12]. The choice of the surgical approach in parotid surgery is particularly relevant because of the extreme anatomic variability of the parotid area and the functional importance of the branches of the FN [5, 13]. Preservation of the FN during parotid gland surgery depends upon its being located without suffering damage [13]. Accurate knowledge of the anatomy of the nerve and considerable perioperative care are essential if trauma is to be avoided. The surgeon must be acquainted with a range of techniques, since anatomical variations may make already established specific approaches difficult [13]. The aim of this study was, therefore, to establish these variations in the cadavers presented for postmortem in Kenyatta National Hospital mortuary to bridge the gap in knowledge in data on black African population which will also assist in performing safe surgical interventions.

1.2 LITERATURE REVIEW

The arborization of the extratemporal FN typically begins within the substance of the parotid gland and ultimately gives rise to the cervical, marginal mandibular, buccal, zygomatic and frontal (or temporal) nerve branches[1]. Several studies have demonstrated variations in the branching patterns of the FN, bifurcation and trifurcation of the main trunk, reanastomosis, looping patterns and morphometric variations in relation to surgical landmarks [4, 5, 8-16]. In addition, various classification systems have been used by different authors to describe the branching patterns[5, 8, 11, 14-16].

Branching patterns

McCormack et al in 1945 studied 100 FNs from cadavers and described the surgical anatomy with special reference to the parotid gland. They described a complex classification of 8 patterns of the FN branching and anastomosis. This was arranged in order of increasing complexity beginning with the simple type and ending with those exhibiting a markedly plexiform arrangement [14]. Dargent and Duroux in 1946 presented 5 main types of FN distribution. The authors dissected 68 FNs from within the substance of the parotid gland. They noted two major classes and five "types" of FN branching from 59 of the 68 dissections. Class 1 (35 cases): FN without anastomoses between branches after their initial branching from the trunk. Class 2 (24 cases): FN with anastomoses between the cervicotemporal branches which form intraglandular plexuses [15].Davis et al in 1956 dissected 350 cadaveric facial halves and categorized the branching pattern of the FN into 6 distinct types (Fig. 1.1). The FN trunk typically gave rise to superior/ upper (temporofacial) and inferior/lower (cervicofacial) divisions. They noted that the marginal mandibular and cervical branches of the FN were exclusively derived from the inferior division, whereas the buccal branch always received some contribution from the inferior division and either none or a variable contribution from the superior division [8].

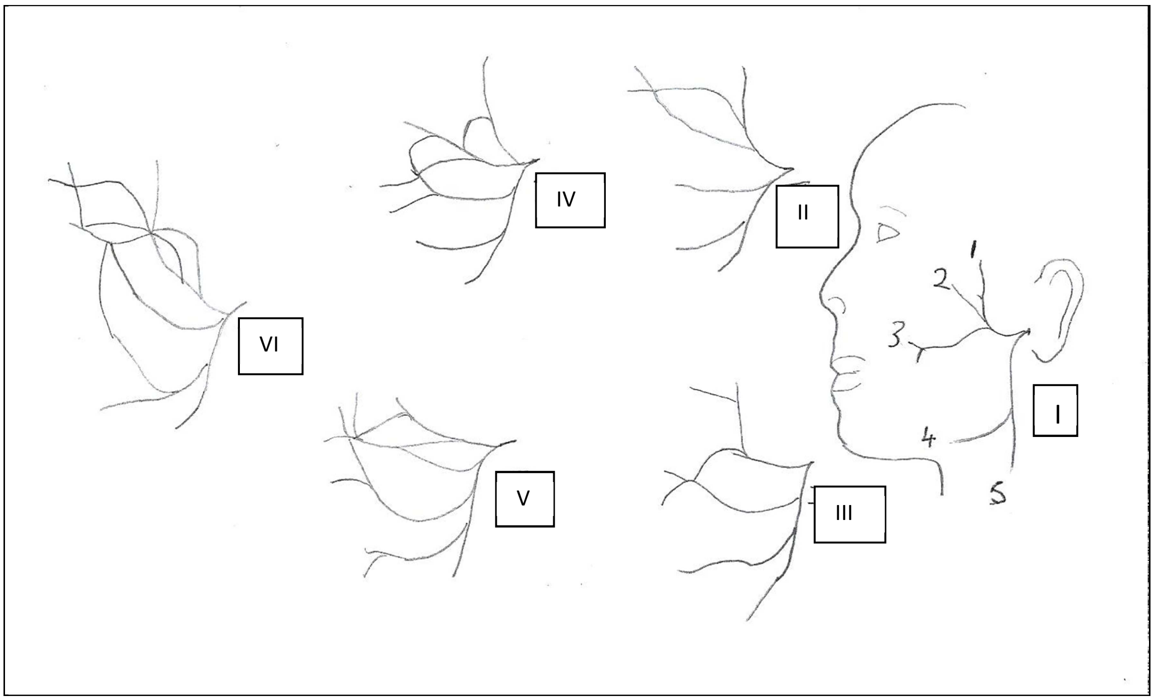


Fig. 1.1. Pattern of extratemporal branching of the FN adapted from Davis et al., 1956. [8]

1. Temporal branch 2.Zygomatic branch 3.Buccal branch 4. Marginal mandibular branch 5. Cervical branch

They found out that type III was most common with a frequency of 26%, followed by type IV - 24%, II -20%, I -13%, V- 9% and VI- 6%.[8]

Baker and Conley reviewed the extratemporal FN anatomy in about 2000 parotidectomy cases in 1979[16]. Their findings suggested that the FN branching pattern was more variable than that noted in the Davis[8] cadaveric studies including the presence of a FN trunk trifurcation with a direct buccal branch in a few instances [15].This was done on live parotidectomy cases and probably explains the more detailed anatomy described as compared to the cadaveric studies[16].

Katz and Catalano in 1987 during live parotid dissection found significant variations in the FN branching that had not been previously reported[11]. In a study of 100 patients during parotid surgery, ninety-nine patients had the FN configurations that could be divided into five main types (Appendix 1). One nerve could not be classified into any of these types because of a bizarre configuration. Twenty-four percent of the patients had a straight branching pattern (type I); 14% had a loop involving the zygomatic division (type II); 44% had a loop involving the buccal division (type III); 14% had a complex pattern with multiple interconnections (type IV); and 3% had two main trunks, one major and one minor (type V) [11].Numerous micro- dissection studies have demonstrated that branching patterns and anastomoses between branches both within the parotid and on the face exhibit considerable individual variation [5,7,9,11,17].

Kopuz et al. (1994) in a cadaveric study in a Turkish population found intraparotideal configuration of the FN and classified as Katz and Catalano[11] did in 1987[9]. Twenty four per cent of the FNs had no anastomoses (Type I); 12% had a ring-like shape anastomosis between the buccal and the zygomatic branches (Type II); 14% of the anastomoses were between the buccal and the other branches in a ring-like shape (Type III); 38% of the FN had multiple complex anastomoses and were named as multiple loops (Type IV); 12% had two main trunks (Type V). The FN distribution in 9(47.3%) were bilaterally similar and in 10(52.7%) were different. A FN trifurcation composed of two main trunks was also established[9].

In parotid surgery, these anastomoses are important and presumably explain why accidental or deliberate division of a small branch often fails to result in the expected FN weakness. [18]

Kwak et al. (2004) classified the branching patterns of the FN according to the origin of the buccal branch into four types (Appendix 3). In type I (13.8% of the cases), the buccal branches arose from the two main divisions of the trunk but not from other branches of the FN. In type II (44.8%), the buccal branches arising from the two main divisions were interconnected with the zygomatic branch. In type III (17.3%) the marginal mandibular branch was noted to send nerve twigs to the buccal branch which originated from the upper and lower divisions. In type IV (17.3%), the nerve twigs from the zygomatic and marginal mandibular branches merged with the buccal branch arising from the two main divisions [5].

Kwak et al. (2004) reported that connections between the lower elements were far less frequent than those among the upper branches of the FN[5]. Davis et al. (1956) reported that the marginal mandibular branch communicated with the buccal branch in only 6.3% of the 350 specimens examined. They further reported that the FNs without connections between branches after their initial branching from the nerve trunk were involved in 60% of the cases[8]. However, a study by Kwak et al. (2004) differed in the sense that, they did not report any of the simple patterns without communication[5]. Unlike Dargent and Duroux (1946), the dissection was extended beyond the anterior border of the masseter[15].

Several authors have reported the possibilities of trifurcation, quadrifurcation, or even a plexiform branching pattern of the FN trunk (Table. 1.1) [5, 9, 15, 19-22]. Salame et al. (2002) identified one case of trifurcation out of 46 cases and Park and Lee (1977) reported its prevalence to have been 4.4% in Koreans [10, 19]. Davis et al. (1956) in their study in a Caucasian population reported 100% bifurcation of the main FN trunk [8]. Kopuz et al. (1994) investigated the FN in the parotid gland in 50 specimens and reported a trifurcation of the main FN trunk in 9 (18%) cases[9]. Kwak et al. (2004) reported 4 cases (13.3%) of trifurcation of the FN trunk[5]. These studies all examined adult cadavers. Ekinci[20] (1999) examined 27 FNs in 14 cadavers and reported bifurcation in 22 cases and trifurcation in 5. Further, they studied the relationship of the FN branching with age. In the full-term foetus the anastomoses were not seen and it appeared like a straight branching pattern. Ekinci (1999) suggested that the frequency of anastomosis increased with age[20]. However, no embryological basis of this finding could be found in the literature reviewed.

Tsai and Hsu (2002) classified the nerve branching patterns into three main categories. Twenty cases (24.7 %) displayed the pattern where the upper and lower trunks of the FN divided, closely followed by the bifurcation of the marginal and cervical branches. In the largest group (34 cases, 42 %), the upper and lower trunks divided, then branched into their respective divisions. Twenty-seven (33.3%) cases had branching of the upper division immediately after the bifurcation of the upper and lower divisions[21]. None of the studies reported cases of no furcation of the FN trunk.

Myint et al. in 1991 carried out fine dissection in 79 facial halves from formalin fixed Malaysian adult cadavers of various races and found 3.8% trifurcation in the FN[22]. The branching patterns were placed in Davis et al. (1956)[8] classification of six types and the frequency of occurrence was type I 11.39%, type II 15.9%, type III 34.18%, type IV 18.98%, type V 7.59% and type VI 12.67%. Type I, the classical textbook pattern was found to have been one of the least common patterns[22].

Table 1.1. Bifurcation and trifurcation of the FN trunk according to various authors.

Author	Bifurcation %	Trifurcation %
Davis et al .,1956	100	-
Park and lee., 1976	95.6	4.4
Katz and Catalano., 1987	100	-
Kopuz et al., 1994	82	18
Ekinci., 1999	81.4	18.6
Salame et al., 2002	97.8	2.2
Tsai and Hsu., 2002	100	-
Kwak et al., 2004	86.7	13.3
Kalaycioğlu et al., 2013	81.3	18.8
Myint et al., 1991	96.2	3.8

Bilateral configurations

In two Turkish studies by Kopuz et al. (1994) and Kalaycioğlu et al. (2014) evaluated bilateral FN configurations. In one, the FN pattern in 9(47.3%) cases were bilaterally the same and in 10(52.7%) of the cases the main trunks were different[9, 17]. There were no statistical differences between branching of the FN on the right and left sides of the faces[9]. Kalaycioğlu et al. (2014) also did not find significant differences between the right and left FNs [17].

Length of the facial nerve trunk

Salame et al. (2002) emphasized the importance of the length of the FN trunk since a segment needs to be sufficiently long to permit anastomosis with the fewest possible manipulations and neither too tense nor too loose[19]. They examined the FN in 46 specimens from its emergence at the stylomastoid foramen to its furcation and reported a length of 16.44 ± 3.20 mm [19]. Kwak et al. (2004) investigated the length of the FN trunk in 30 subjects with a measured value of 13.0 ± 2.8 mm. They also found that the average depth of the stylomastoid foramen from the skin surface was 21.0±3.1 mm[5]. In an Indian study, Nishanthi et al. (2006) found that the length of the FN trunk from the stylomastoid foramen to the bifurcation was 18.51 ± 3.80 mm[23].

Table 2.1. Length of the FN trunk according to various authors.

Author	Length (mm)
Dargent and duroux, 1946	13
Holt, 1996	21
Salame et al., 2002	16.44
Cannon et al., 2004	9.38
Kwak et al., 2004	13
Pather et al, 2006	14
Nishanthi et al, 2006	18.51
Average	**15.05**

Racial differences

Racial differences have been noted in some studies. In a Korean population, the results indicated that the communicating branches between the buccal and marginal mandibular branches occured more frequently in Koreans than Caucasians[5]. In addition, Wang et al. (1991) reported a 60% prevalence of these communicating branches in the Chinese[24] while Niccoli and Varandas (1998) reported 9% prevalence in Spanish cases[25]. Myint et al.(1992), in a Malaysian study found no significant difference in the percentage of each type between the Malaysian population and that of the Koreans, though some differences with Caucasians were noted in three uncommon types[22]. Myint et al. (1992) also found out that the distance from the bifurcation of the FN was shorter in the Malaysian population compared with studies done on Caucasian subjects. They postulated that a longer distance between the bifurcation of the FN and the angle of the mandible in Caucasians could have been due to a larger stature, a bigger and stronger jaw or a combination of both factors in Caucasians when compared to Asians.[22] Kopuz et al (1994), in a study in a Turkish population also suggested that race may be an important factor in the branching of the nerve[9]. No African studies were found in the literature reviewed.

Table 3.1. The percentage of branching pattern (according to Davis et al.[8] classification) of the FN in Caucasian, Korean and Malaysian subjects [22].

Type of branching	Davis et al[8] 1956	Park & Lee[10] 1977	Bernstein &Nelson[40] 1984	Katz & Catalano[11] 1987	Myint et al[22] 1991
I	13	6.3	9	24	11.39
II	20	13.5	9	14	15.19
III	28	33.4	25	44	34.18
IV	24	23.4	19	14	18.98
V	9	6.3	22	3	7.59
VI	6	17.1	16	0	12.67

Minor trunks

While many articles have carefully described the length of the FN trunk and branching patterns, the minor trunk of the FN is rarely reported. Katz and Catalano (1987) reported three cases (3%)as presenting with two main trunks known as the major and minor trunks with the latter joining the larger temporofacial division, the origin of the main buccal branch[11]. Kopuz et al (1994)[9] reported 18% cases with a minor trunk similar to the description by Katz and Catalano (1987)[11]. Park and Lee (1977) reported 4.4% in their series. Thus, a surgeon should bear in mind that even after finding two main facial nerve trunks, a third minor trunk could still be present and could be exposed to injury[10].

Surgical landmarks

Numerous soft tissue and bony landmarks have been proposed to assist the surgeon in the early identification of this nerve [12, 13, 26-32]. There is still dispute within the literature as to the most effective method, if any, of locating the nerve [7, 13]. Identification of the nerve trunk with the aid of the following landmarks have been studied, namely, the origin of the posterior belly of digastrics muscle(PBDM), the styloid process, the mastoid process, the tympanomastoid suture (TMS), the tragar pointer (TP) and the bony ridge at the anteroinferior margin of the external auditory meatus (EAM) [19,29-31]. From descriptions of these and other landmarks used to identify the main stem of the FN, one could deduce that no conclusive scientific evidence exists to demonstrate that any one of the landmarks is more reliable than the other in the identification of the FN [27, 36.] However, bony structures have been found to be more suitable as anatomical guides because of their rigid and reliable anatomical location[29].

The reliability of soft tissue landmarks varies. It is known that the anatomy of soft tissue structures could be distorted in infants, children, previous surgical intervention, intensive scarring and the extent of a tumor itself and creates exceptionally difficult problems in the execution of basic surgical techniques [28]. Both the length and curvature of the styloid process are variable, therefore, rendering it an equally unreliable landmark [34]. Other criticisms concerning one method or another include no sense of depth, unreliable measurements and the variability from retraction, the danger from being too deep or the necessity for additional dissection [32].

Another landmark considered as dependable is the lowermost medial projection of the TP or cartilage, which lies anterior to the opening of the external acoustic meatus [30]. This ‘‘pointer’’ points directly to the FN trunk upon exiting the stylomastoid foramen [30]. The FN exits 1 cm below and medial to the tip of the TP [31]. One problem with using the TP is that various observers interpret the definition and direction of the ‘‘pointer’’ differently. Difficulty to decide on the position of the tragal ‘‘pointer’’ exists because it is mobile, asymmetrical and has a blunt irregular tip [29].

Al Kayat and Bramley (1979) were the first to study the FN topography by measuring the course of its branches and then correlating the measurements with the site of the preauricular incision[33]. There were no significant variations in topography with age and gender. A study by Rea[26] to measure the distance from four of the most commonly used surgical landmarks to the main trunk of the FN namely the PBDM, the TP, the junction between the bony and cartilaginous EAM and the TMS showed that the main trunk of the FN was found 5.5+/-2.1mm from the PBDM, 6.9+/-1.8 mm from the TP, 10.9+/-1.7 mm from the EAM and 2.5+/-0.4 mm from the TMS. It was shown that the TMS could be used as a reliable indicator for locating the main trunk of the FN. In addition, this study also demonstrated a statistically significant difference between the sexes in relation to the two bony landmarks used here, the EAM and the TMS, with the FN found further away from those landmarks in females compared to males[26].

Nishanthi et al. (2006) found the shortest distances from the TP to the FN trunk and to the bifurcation were 10.08 ± 2.34 mm and 13.97 ± 2.72 mm, respectively. The distance from the bifurcation to the mastoid tip was 16.28 ± 2.87 mm, from the bifurcation to the most caudal point of the EAM was 19.64 ± 2.98 mm and from the bifurcation to the lowest point of the postglenoid tubercle was 23.83 ± 3.28 mm[23]. Another study by Pather et al.(2006) found the distance of the

FN trunk from each of the surrounding landmarks ranged from (mm): TP, 24.3 to 49.2 (mean 34); PBDM, 9.7 to 24.3 (mean 14.6); EAM, 7.3 to 21.9 (mean 13.4); TMS, 4.9 to 18.6 (mean 10.0); styloid process, 4.3 to 18.6 (mean 9.8); transverse process of the axis, 9.7 to 36.8 (mean 16.9); angle of the mandible, 25.3 to 48.69 (mean 38.1)[12].

Table 4.1 Comparison between proximity of FN to various landmarks

Landmarks	**Study**	
	Mean distance(mm)	
	Rea et al[26]	Pather et al[12]
Posterior belly of digastrics	5.5	14.6
Tragar pointer	6.9	34
External acoustic meatus	10.9	13.4
Tympanomastoid suture	2.5	10.0
Styloid fissure	-	9.8
Transverse process of axis	-	16.9
Angle of mandible	-	38.1

The results demonstrated that the PBDM, TP and transverse process of the axis are consistent landmarks to the FN trunk. However, it should be noted that the TP is cartilaginous, mobile and asymmetrical and has a blunt, irregular tip. This study advocated the use of the transverse process of the axis as it is easily palpated, does not require complex dissection and ensures minimum risk of injury to the FN trunk[12].

Other landmarks have been attempted in identifying the FN such as the stylomastoid artery (SMA) [13]. In a clinico-anatomic study, Tahwinder et al. (2009) reviewed 100 routine parotidectomies and dissected 50 cadaveric hemifacies to study the SMA relations to the FN trunk. They consistently identified a supplying vessel, SMA, which tends to vary less in position than the FN. Following this vessel, a few millimetres inferiorly and medially, the FN trunk, which it supplies, could be identified with relative ease. The study concluded that the SMA could supplement other landmarks used in parotid surgery[13]. This further highlights the difficulty in using one single landmark to identify the facial nerve with accuracy and consistency[13]. Racial differences have also been studied in the relationship between the FN and TMJ.

In a study by Woltmann et al. (2000), the relationship between the distances of the temporal and cervicofacial branches of the FN relative to the TMJ was examined in 92 facial halves from 56 adult cadavers. African and Caucasian males frequently had a temporal branch more distant from the EAM (1.59 cm) and the tragus (2.09 cm) when compared to the respective females (1.25 cm and 1.82 cm). In mesocephalic African and Caucasian males, the cervicofacial trunk frequently passed closer to the EAM (1.76 cm and 2.26 cm, respectively) than in brachycephalic African males (2.30 cm) and in dolicocephalic Caucasian males (2.95 cm). Mesocephalic Caucasian males and brachycephalic African males had larger distances for the cervicofacial branch (2.26 cm and 2.30 cm), respectively, than the corresponding mesocephalic (1.4 cm) and brachycephalic (1.8 cm) females. The location of the temporal branches and cervicofacial trunk of the FN increases the risk of lesions to these nerves during access to the TMJ[35].

Apart from racial variations which could be explained by various morphologies of the cranium, no other reason could be found in the literature reviewed could explain the variations described.

1.3. STATEMENT OF THE PROBLEM

FN damage leads to transient or permanent facial palsy. Comprehensive understanding of the anatomy of the FN is important in surgery involving the parotid gland, TMJ, craniofacial trauma, mastoid bone surgery among others. Iatrogenic injuries can occur to the FN during such surgical procedures. Correct surgical approaches and identification of the FN trunk and its branches is critical in the avoidance of any iatrogenic injuries. Variant anatomy in the FN in different individuals and populations has been described in the literature, as well as racial differences. No single anatomical landmark has been shown to be totally reliable in the identification of the FN during surgical procedures. Different morphometric data on the FN exist but with large variations among different populations and racial groups.

1.4. JUSTIFICATION OF THE STUDY

There is the paucity of data in the local population on the FN as hardly any Kenyan studies were found in the literature search. There is need to obtain data on the proximity and reliability of anatomical landmarks commonly used in identifying the FN during surgery. This will be important in the avoidance of nerve damage which has severe functional and aesthetic outcomes. This should also help in planning of surgical approaches to the region. The need to establish dimensions of the FN is essential in primary nerve repair and in nerve grafts or re-anastomosis.

1.5. OBJECTIVES

BROAD OBJECTIVES

To investigate and document extracranial anatomical variations in the FN anatomy.

SPECIFIC OBJECTIVES

1. To establish the branching patterns of the FN.
2. To determine the proximity of FN to various landmarks commonly used in the identification of the nerve during surgery.

1.6. VARIABLES

a) Independent variables

1. Gender.
2. Side (right/left).

b) Dependent variables

1. Branching patterns of the FN (Davis classification type I-VI[8]).
2. Number of FN trunks.
3. Length of FN trunk.
4. Distance of FN trunk at furcation from
    a. Tragal pointer.
    b. Tympanomastoid fissure.

c. External auditory meatus.

d. Posterior belly of the digastrics.

e. Styloid process.

f. Temporomandibular joint.

g. Angle of mandible.

2. MATERIAL AND METHODS

2.1. STUDY DESIGN

This was a descriptive cross- sectional study design using quantitative techniques of data collection. The data included morphometric parameters of the FN as well as describing the various patterns of its extracranial distribution.

2.2. STUDY AREA

The study was conducted at the Kenyatta national hospital (KNH) mortuary. A pilot dissection on 7 cadavers was done in the university of Nairobi anatomy department topographic anatomy laboratory for familiarization and calibration. The hospital is the main tertiary and also the largest public referral hospital serving the whole country. It is also a teaching hospital in conjunction with the University of Nairobi College of health sciences. The mortuary serves patients who die in the hospital who come from all parts of the country.

2.3. STUDY POPULATION

The study population was cadavers in KNH mortuary. Kenya is made of a population of 38.6 million people as per 2009 census with 43 ethnic groups, including a minority of 1% non-African groups consisting of Arabs, Indians and Caucasians.

2.4. SAMPLE DESIGN AND PROCEDURE

I. SAMPLING DESIGN

Convenient sampling of cadavers presented for post-mortem in the mortuary was selected. They were all well preserved and refrigerated fresh cadavers before any tissue fixation or embalming was done. All those that met the inclusion criteria and those cadavers presenting for post-mortem were selected within the study period. Informed consent was sought from the next of kin.

II. SAMPLE SIZE DETERMINATION

Sample size was calculated using the following formula proposed by Varkevisser et al using variance [38].

$$n = \frac{4\delta^2(z_{crit} + z_{pwr})^2}{d^2}$$

Where,

n= sample size

δ^2 = variance (square if standard deviation)

Z_{crit} =1.96 (for 95% confidence interval)

Z_{pwr} = 0.84 (for 80% power)

d^2 = difference in means (effect size)

= ½ standard deviation

Using a previous study by Nishanthi et al. (2006) the length of the facial nerve trunk was found to have been 18.51 +/- 3.80 mm[23].

$$n = \frac{4(3.8^2)(1.96+0.84)^2}{1.90^2}$$

n= 39

Minimum of thirty nine FNs from bilateral dissection of 20 cadavers.

2.5. INCLUSION CRITERIA

All well processed and preserved fresh adult cadavers in the mortuary presented for post-mortem within the study period were selected.

2.6. EXCLUSION CRITERIA

Any cadavers with facial malformations, either congenital or acquired, gross pathologies in the head and neck region as well as distorting or disfiguring injuries were omitted. Also, cadavers with any tissue macerations, burns or evidence of surgical operation in the parotid and infratemporal region and those whose relatives did not consent were excluded.

2.7. DATA COLLECTION TOOLS

Data collection sheet

<u>Aids to data collection</u>

Digital photographs

Dissection kit

Magnification lenses

Rulers

Pair of dividers

Calibrated flexitape

Digital camera and photography

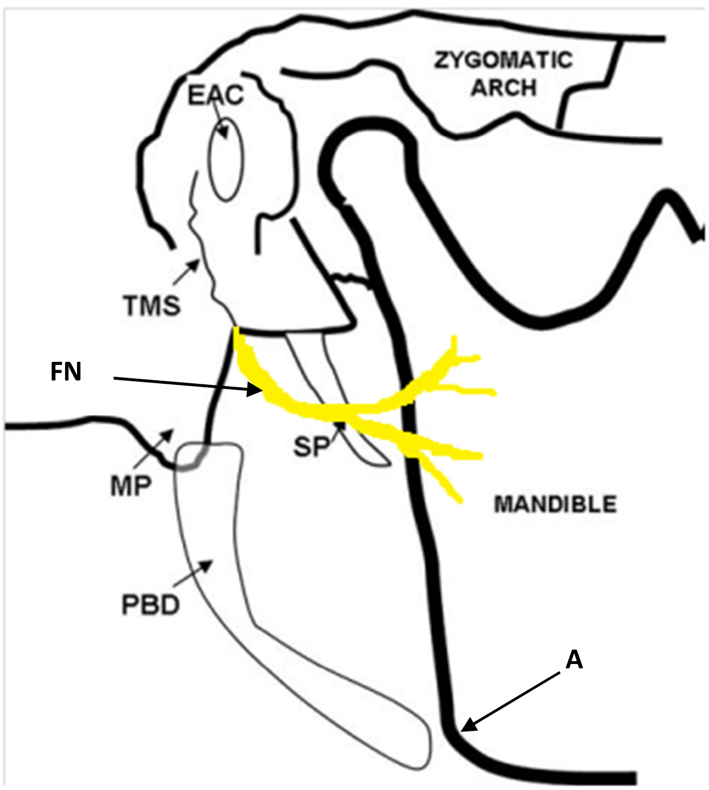
2.8. DATA COLLECTION PROCEDURE

Facial dissection of cadavers using a standard dissection kit was done during autopsies. The facial nerve was exposed using standard thoraco-cervical and coronal incisions done during autopsy. These are incisions used for neck dissection and craniotomies to expose the skull and brain as shown in plate 1.

A mastoid to mastoid incision for craniotomy which joins the u -shaped cervical incision along the lateral aspect of the neck was made. This was behind the ears and beyond the hairline to conceal the incision and avoid facial disfigurement. A flap was raised with a cut through the EAM with displacement anteriorly. The mastoid was identified and dissection performed anteriorly to expose the parotid gland and further the TMS, EAM and TP which were used to identify the FN. Dissection was done to follow the nerve from the exit at the stylomastoid foramen posteriorly and anteriorly to follow its furcation.

Plate 1. Standard autopsy incision used to expose the FN.

Dissection to identify the FN trunk and various surgical landmarks such as the TP, TMS, EAM and PBDM and traced back to the emergence from the stylomastoid foramen as shown in plate 2. Superficial parotidectomy to expose the FN branches was done up to the anterior border of the masseter. The specimens were photographed for documentation as demonstrated in plate 2-6. A descriptive morphometric study describing the relationship between the FN and the various landmarks as shown in Fig. 2.2 was done using a pair of dividers, measuring flexitape and transferred to a measuring ruler calibrated in millimeters. Branching patterns and re-anastomotic loops were also documented. Branching patterns were recorded in terms of the number of branches off the main trunk and final divisions pattern based on the classification by Davis et al[8] (Plate 2-6). No specimen was taken from the cadavers and tissues were placed back to as close to their anatomic positions as possible. Meticulous closure of the incisions was done by the mortuary assistants. Data collected were presented in figures and morphometric data presented in specially designed tables (appendix i).



TMS-tympanomastoid suture

PBD- posterior belly of digastrics

MP-mastoid process

SP- styloid process

EAC-external auditory canal

A - Angle of the mandible

FN- Facial nerve

Figure 1.2.Diagram showing relationship of FN to various landmarks modified from Panther et al.[12].

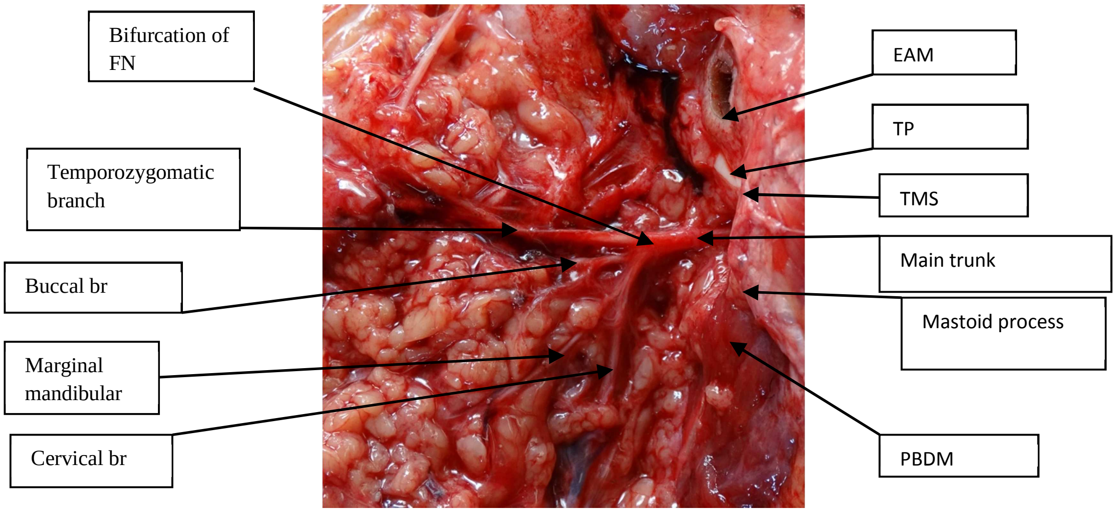


Plate 2. Type I branching pattern- straight branching pattern with no anastomosis

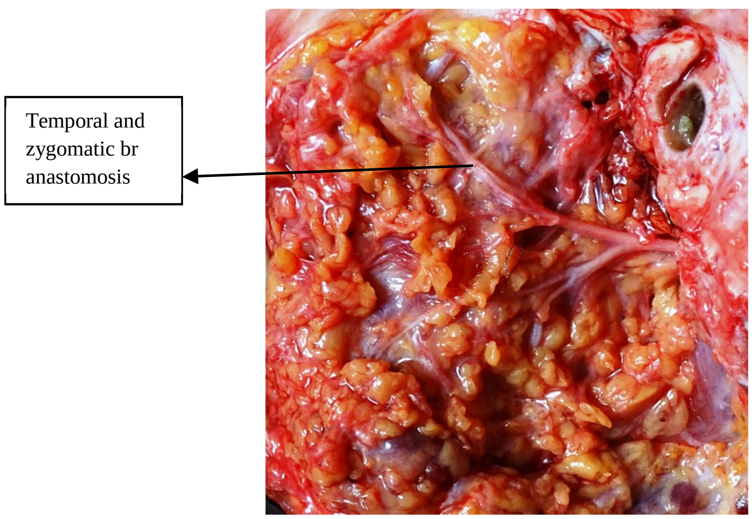


Plate 3. Type II branching pattern- zygomaticotemporal anastomosis

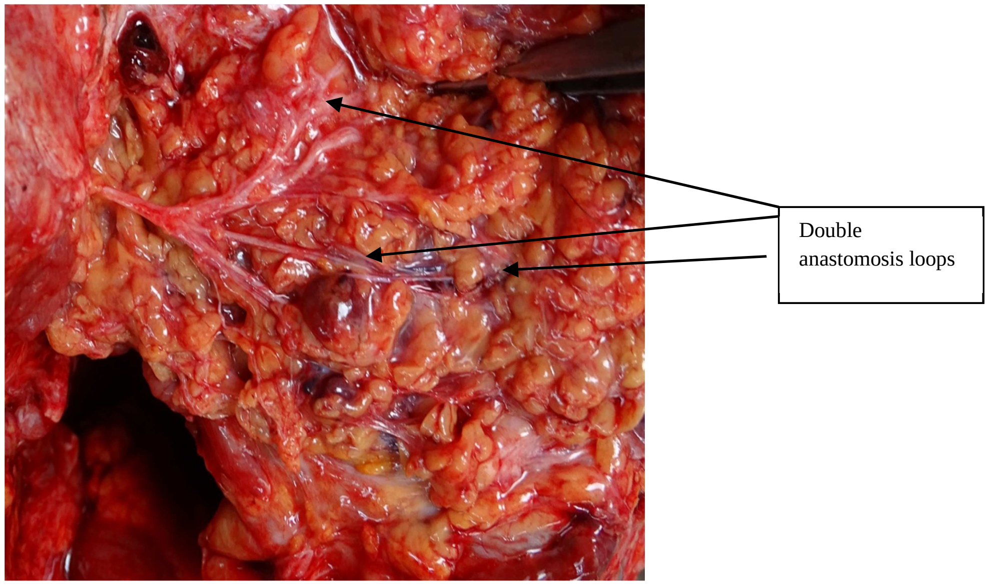


Plate 4. Type IV branching pattern- double anastomosis.

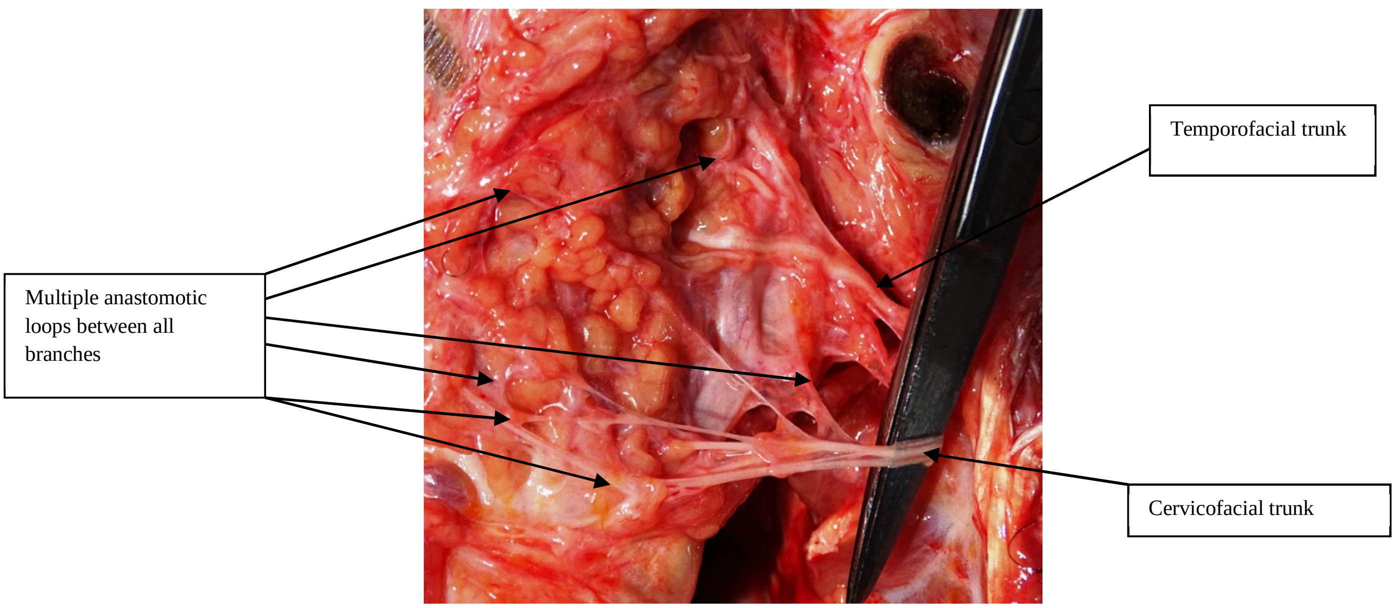


Plate 5. Type VI branching pattern showing complex anastomotic pattern

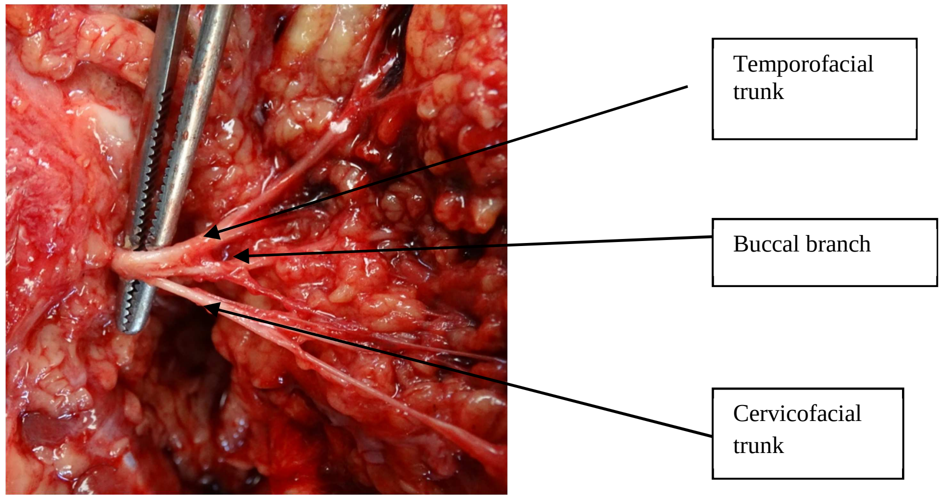


Plate 6. Trifurcation of the FN trunk

2.9. DATA ANALYSIS AND PRESENTATION

Data were coded and analyzed using the SPSS version 18.0 software from SPSS inc.IL. Descriptive analysis was done and presented using frequency diagrams, tables and figures.

Statistical tests (Student t, Wilcoxon sign rank and Mann Whitney u test) were done to determine whether there was a significant difference between males and females, right and left FNs. Differences between dependent variables and independent variables were analyzed using the Spearman rank order correlation and Pearson's product moment correlation. The significance level was set at $P<0.05$.

2.10. ERRORS AND BIASES

Identification of fine branches and anastomosis especially microscopic ones was a challenge. Due to the soft tissue nature of the specimen dimensions of the nerve change dependent on traction forces applied and position of the head. Accuracy of measurements of some landmarks was also affected by their anatomical shape and form such as the angle of mandible whereby the gonion point is a derived point. Other such landmarks were the TP, TMJ and TMS.

2.11. STUDY LIMITATIONS

The sample was assumed to have been an accurate representation of all cadavers presenting in the mortuary. The dissection was limited to the anterior border of the parotid gland to avoid facial disfigurement. The difference in body size and physique and profile of the head may have an effect on the different morphometric data obtained.

2.12. MINIMIZING ERRORS AND BIASES

There was no or minimal tissue distortion as the cadavers were fresh and well refrigerated. To assess intra-observer variability every 5^{th} specimen was measured twice and repeat measurement was done by the resident pathologist conducting the autopsies as well as the first supervisor. The nerve patterns were also photographed for verification by one of the supervisors (Dr F. Butt), a lecturer in Human anatomy department.

2.13. ETHICAL CONSIDERATIONS

- Ethical approval was obtained from the Kenyatta National Hospital/ University of Nairobi ethics and research committee (P112/03/2014).
- Informed consent was sought from the next of kin prior to the autopsy. This was done days prior to the autopsy and was allowed considerable time to deliberate. Only cadavers of the next of kin who gave informed consent were recruited and the next of kin were allowed to withdraw the cadavers from the study at any point without prejudice.
- Information gathered from the study participants was kept confidential.
- All the raw data collected both hard and soft copies were kept in a locked cabinet in the department and password protected database by the researcher. This was subsequently destroyed upon completion of the study by incineration for hard copies and deletion for softcopies.
- Permission was sought from the University of Nairobi, departments of Human Anatomy and Human Pathology as well as the Kenyatta National Hospital mortuary.

CHAPTER 3

RESULTS

Twenty fresh cadavers were dissected (40 FNs) among which 12(60%) were male while 8(40%) were females. The frequency of various branching patterns according to Davis et al. (1956) classification was as illustrated in Fig. 1.3. The most frequent pattern was type I at 25% while type V 5% having been least frequent.

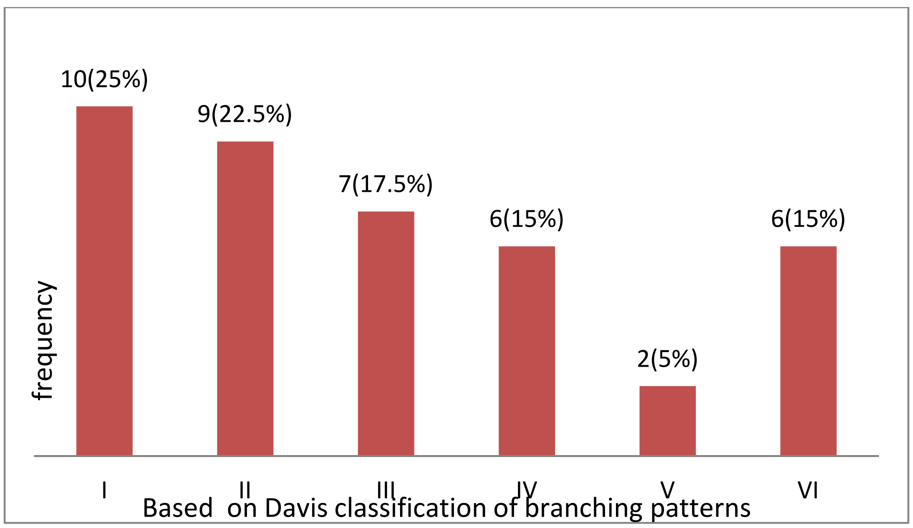


Fig. 1.3. Distribution of branching pattern (Davis et al classification I-VI)

Comparison of the branching pattern was done between the genders(Fig. 2.3) and Kruskal-Wallis H test showed that there was a no statistically significant difference in the branching patterns between the genders (Davies et al. classification I-VI), $\chi2(1) = 1.127$, $p = .288$.

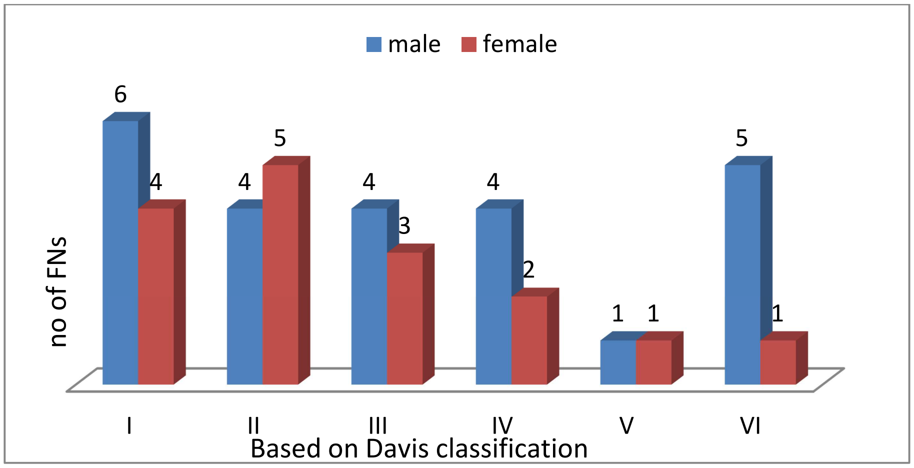


Fig 2.3. The distribution of branching patterns according to gender

The various types of branching patterns (Davies et al.(1956) classification were photographed and documented demonstrating the various levels of complexity in the anastomosis[8]. Type I had no anastomosis between the branches while type VI had the most intricate pattern with anastomosis among all the branches except the cervical. The distribution of the branching patterns (Davis et al. classification) according to side was compared as demonstrated in Table 1.3.

Table 1.3. Distribution of branching patterns by side.

	Right	Left
Branching pattern		
I	**5**	**5**
II	**4**	**5**
III	**3**	**4**
IV	**4**	**2**
V	**1**	**1**
VI	**3**	**3**

The FN trunk was found to branch into two (bifurcation) in 32 (80%) of the cases and three (trifurcation) in 8 (20%) cases. No case of quadrification was noted in this study. In males , 19 (79%) of the FNs bifurcated, while 5 (20.8%) trifurcated (n=24). In females 13 (81.25%) FNs bifurcated , while 3 (18.75%) trifurcated (n=16) as shown in Fig. 8.3. One case of a minor trunk emerging from the stylomastoid foramen was observed (Fig. 9.3) which anastomosed with the temporal branch of the FN. Eleven (55%) of the cadavers had similar branching patterns between the right and the left sides, while 9 (45%) had dissimilar patterns. On furcation of the main trunk, 14(70%) cadavers had similar furcation type between the right and left sides while 6 (30%) had different types.

Table 2.3. Wilcoxon signed rank test for branching patterns (Davies et al classification I-VI) and bifurcation of main trunk.

	Side								
	Left		Right						
	M	**SD**	**M**	**SD**	**-Ranks**	**+Ranks**	**Ties**	**Z**	**P**
Branching pattern (Davies et al classification I-VI)	2.80	1.82	3.0	1.81	6	3	11	-.660	.509
Bifurcation of main trunk	2.15	.37	2.25	.44	2	4	14	-.816	.414

On comparison between the branching patterns on the right with the left sides, a Wilcoxon signed-rank test did not elicit any statistically significant change in the left and right side branching pattern (Z = -.660, p = .509). Similarly no statistically significant change in the left and right side bifurcation of the main trunk (Z = -.816, p = .414) was elicited.

Various measurements were performed of the morphometric characteristics of the FN. The length of the nerve was 16.14 mm(+/- 3.28), distance from the TP was 9.87mm(+/- 2.41), TMS 5.81 mm(+/- 1.28), EAM 15.64 mm(+/- 2.74), PBDM 8.09 mm(+/-1.78), styloid process 16.48mm(+/- 5.47),TMJ 22.55 mm((+/- 1.99) and angle of the mandible37.98 mm (+/- 4.45). The styloid process was missing in 9 (22.9%) of the hemifacial dissections. Table 3.3 shows these descriptive data.

Table 3.3. Descriptive statistics of the morphometric data.

	Statistics					
Variable	**N**	**M**	**SEM**	**SD**	**Variance**	**Range**
Length of trunk (mm)	40	16.14	.52	3.28	10.77	11.00
TP	40	9.87	.38	2.41	5.80	11.90
TMS	40	5.81	.20	1.28	1.64	6.00
EAM	40	15.64	.43	2.74	7.50	12.00
PBDM	40	8.09	.28	1.78	3.15	7.0
Styloid process	31	16.48	.98	5.47	29.98	22.50
TMJ	40	22.55	.31	1.99	3.95	7.00
Angle of mandible	40	37.98	.70	4.45	19.77	18.00

Comparison of the morphometric data between the right and left sides showed minimal differences in the means and standard deviation as shown in Table 4.3. The mean lengths of the trunk were closely related between the 2 sides with a mean on the right of having been 16.15 mm compared to 16.13mm on the left side. On the other hand the angle of the mandible showed the biggest difference in the mean distance of 36.95 mm on the left as compared to 39 mm on the right side with a SD of 4.76 on the left and 3.96 on the right which was statistically significant(p=.020).

Table 4.3. Descriptive statistics of the left and right side variables

	Statistics						
	Left Side			**Right side**			**t-test**
	N	**M**	**SD**	**N**	**M**	**SD**	**P**
Length of trunk (mm)	20	16.13	3.09	20	16.15	3.55	.965
TP	20	9.83	2.94	20	9.90	1.80	.893
TMS	20	5.75	1.26	20	5.88	1.33	.555
EAM	20	16.03	2.74	20	15.25	2.75	.088
PBDM	20	8.05	1.79	20	8.13	1.81	.830
Styloid process	15	16.20	5.52	16	16.75	5.60	.862
TMJ	20	22.40	2.04	20	22.70	1.98	.560
Angle of mandible	20	36.95	4.76	20	39.00	3.96	.020*

*P<.05

Comparison of variables across gender

Independent sample t Test was used to analyse the difference of the various measurements across the genders. The results showed no statistically significant differences in the length of the trunk as well as distance from the various landmarks across gender as shown in Table 5.3.

Table 5.3: Results of Independent Sample T Test for variables by gender.

	Gender										
	Male			**Female**			**95% CI for Mean Difference**				
Variables	**n**	**M**	**SD**	**N**	**M**	**SD**	**Lower**	**Upper**	**df**	**T**	**p**
Length of trunk	16	16.38	3.24	24	15.98	3.37	-1.77	2.56	38	0.370	0.714
TP	16	10.06	2.08	24	9.73	2.64	-1.26	1.92	38	0.419	0.678
TMS	16	5.78	1.05	24	5.83	1.43	-0.90	0.79	38	-0.125	0.902
EAM	16	15.97	2.19	24	15.42	3.08	-1.25	2.36	38	0.620	0.539
PBDM	16	8.16	1.67	24	8.04	1.88	-1.06	1.29	38	0.197	0.845
Styloid process	12	16.58	6.00	19	16.42	5.28	-4.04	4.36	29	0.079	0.938
TMJ	16	22.69	2.02	24	22.46	2.00	-1.08	1.54	38	0.353	0.726
Angle of mandible	16	38.13	4.32	24	37.88	4.62	-2.69	3.19	38	0.172	0.864

Correlation between the left and right attributes

A Spearman's rank-order correlation was used to determine the relationship between the left and right side branching pattern of the FN. There was a positive correlation between the left and right side branching pattern which was statistically significant (r_s = .643, p = .002). A Spearman's rank-order correlation was used to determine the relationship between the left side bifurcation of the main trunk and the right side bifurcation of the main trunk. There was a positive correlation between the left and right side bifurcation of the main trunk which was not statistically significant (r_s = .081, p = .735).

The Pearson correlation test (Table 6.3) between the left and right side variables showed that there was a positive correlation which was statistically significant in the length of the trunk (.000), TP (.003), TMS (.000) EAM (.000), styloid process (.000), PDMS (.003) and angle of the mandible (.001).The TMJ did not show a statistically significant correlation between the left and right FNs.

Table 6.3. Association between Left Side Attributes and Right Side Attributes

Pearson Product-Moment Correlation		
Attribute	**Coefficient, r**	**P**
Length of trunk (mm)	.727**	.000
Distance of trunk from (mm)		
TP	.628**	.003
TMS	.743**	.000
EAM	.753**	.000
PBDM	.633**	.003
Styloid process	.691**	.004
TMJ	.365	.114
Angle of mandible	.673**	.001

** p < .05

CHAPTER 4

4.1 DISCUSSION

The FN is highly varied and complex in its extra-temporal course. Various studies dating as early as in the 1930s have illustrated this varied anatomy[14, 15]. This study confirms the variations in the anatomy of the extracranial FN in a Kenyan population. It demonstrates the various divisions and anastomotic patterns of the FN branches that a surgeon will encounter in the parotid and retromandibular regions. As described by different authors[11, 16, 22], it is difficult to classify the patterns in rigid models as described by the Davis et al classification [8] and, therefore, the closest pattern was taken for classification. This could also have had an influence in the findings as these classifications are not always reproducible. There are numerous classifications as different authors attempt to come up with accurate and reliable parameters. This, therefore, renders comparisons between different studies and populations complex. Earlier studies by Davis et al. in 1956, showed the highest frequency of mainly the type III (28%) pattern[8]. Our study found type I (25%) to have been the commonest type compared to Davis et al. who found a frequency of 13%. Types II and III closely followed with frequencies of 22.5 and 17.5%, respectively as compared to Davis et al. at 20% and 28%, respectively. The least common types found in this study were types IV, V and VI at 15%, 5% and 15%, respectively. Similarly, types V and VI were also the least common types in the Davis et al. study at 9 and 6%, respectively, while the frequency of type IV was 24%. However, the frequency of these branching patterns shows a wide variation as documented by different authors[10,11,22,40].

The frequency of type I (25%) was found to have been higher than in some of the previous studies[10, 11, 22]. Kopuz et al. (1994) found a frequency of 24% which was almost similar to this study while Park and Lee (1997) found type I to have been among the least common at 6.3%[9, 10]. In their study the dissection was extended to the entire face and they found anastomosis distal to the parotid gland parenchyma. The study also incorporated the use of a microscope to identify micro- anastomosis invisible to the naked eye[10]. This was also similar to a study by Kwak et al. (2004) who did not find any pattern without communication although they used a different classification type and used microscopic dissection technique[5]. However, in our study the dissection did not extend to the entire face and a microscope was not utilized in the dissection which could possibly explain the higher incidence of the straight branching pattern. Lack of anastomosis exhibited in type I would lead to a higher incidence of FN paralysis if one of the branches was injured. The frequency of type II compared favorably with Davis et al.(1956) who found a frequency of 20%. Myint et al.(1992) found a frequency of 15.19%, while Katz and Katalano found 14%[8,11,22] . Type II could allow for the sacrifice of one of the branches of the temporozygomatic loop without permanent damage.

The type III frequency of 17.5% was comparatively lower than most studies. Bernstein et al. (1984) reported 25% in a Caucasian population, while Myint et al.(1992) reported 34.18% and Park & Lee (1977) reported 33.4% among the Malaysian and Korean populations respectively[10,22,41]. The frequency of Type IV was found to have been 15% in this study. This compared well with studies by Katz & Katalano (1987) who found a frequency of 14%; Myint et al.(1992) reported 18.98% while Bernstein et al.(1984) reported 19% [10 11,41]. Types III and IV each have more elaborate branching patterns which may allow for the sacrifice of the buccal branches. Type V was the least common (5%) and this is in tandem with reports by other authors' findings which all ranged between 3-9%[8, 10, 11, 22]. Type V, although showing extensive anastomosis in the upper part of the face, it has no additional contribution to the mandibular branch. Thus, surgeons should take precaution in surgery of the mandibular region.

The present study found a frequency of 15% in type VI. In comparison Davis et al. (1956) had a lower frequency of 6% while other studies ranged between 12.67 to 17.1% in tandem with our study. Type VI had the most complicated pattern with anastomosis between every branch except the cervical one. This complex anastomotic pattern would lead to less incidences of facial paralysis in case of iatrogenic injury to any of the branches. . However, no studies have attempted to compare the incidence of FN paralysis following damage to the branches and branching types in the same population. Temporal and mandibular branches of the FN are most prone to injury because they rarely have any anastomosis with other branches of the nerve [22].

Racial differences have been demonstrated in frequencies of various types between Asians and Caucasians [22, 10, 32] .When compared with the studies done in different races, the present study shows that type I was the most frequent pattern while Caucasian and Asian studies reported a higher frequency of type III [8, 11,40.].

The FN was found to bifurcate in 80% of the cases in this study. Studies by Ekinci et al.(1999), Kalaycioglu et al.(2014) and Kopuz et al.(1994) had similar findings with bifurcation of 81.4, 81.3, 82%, respectively[9,17,20]. This is in contrast with Davis et al.(1956) and Katz and Catalano (1987) who reported 100% bifurcation while Myint et al.(1992) reported 96.2% and Salame et al.(2002) reported 97.8%[8,11,19,22].Trifurcation in the present study was observed in 20% of the cases compared to other studies which reported trifurcation of 18.6, 18.8, and 18%, respectively[9,17,20].

Bilateral comparison for the FN branching pattern did not elicit any significant difference between the right and left sides. Eleven cases were similar while 9 had different patterns. Similarly on furcation of the main trunk, 14 were similar while 6 were not. There was no significant difference between the left and right side furcation types. The results from this study tallies with Kopuz et al. (1994) and Kalaycioğlu et al. (2014) on bilateral configurations [9, 17]. There was a statistically significant positive correlation between the right and left side branching pattern. Previous studies had not attempted to correlate the bilateral configuration. This could be of surgical relevance in case of bilateral surgical procedures in order to predict the opposite side configurations. However, on furcation types there was positive correlation which was not significant. In an attempt to demonstrate the significance of these differences, an Iranian study suggested that variability in the branching patterns of the nerve creates variability in facial animation, both between patients and ethnic groups and between the sides of the face[42].

The length of the FN trunk was found to have been 16.15(+/- 3.28) mm and there was no statistical difference between the right and left sides. Different authors have found varied lengths of the FN; Salame et al. (2002) reported 16.44mm, Kwak et al. (2004) reported 13.0mm, Nishanti et al. (2006) reported 18.51mm and Holt reported (1996) 21mm[5,19,23,40]. The average length from the literature reviewed was 15.05 mm. These differences could partly be attributed to the nature of the different studies as some were on already fixed cadavers and others were on live patients during parotidectomies. The current study was on fresh cadavers and tissue changes were, therefore, minimal. Previous authors have emphasized the importance of knowledge of the FN trunk length and its relevance in performing surgical anastomosis and nerve grafts[19, 23]. There are no studies showing significant racial differences in FN trunk length. There were also no statistical differences between the genders in keeping with previous studies[12, 17].

Identifying relationships between the main trunk of the FN and its network of branches to soft tissues and bony fixed points contributes to safer aesthetic and reconstructive techniques[42]. There are several landmarks used in the location of the FN during surgery with differing accuracy. Various authors have found very varied values for some of these landmarks. The distance of the FN trunk to the PBDM was found to have been 8.09mm in the present study. In comparison, Pather et al. (2006) found it to have been 14.6 mm and Rea et al (2010 found 5.5 mm[12,26]. The PBDM has the advantage of lying in the same plane as the FN trunk and also easy to identify, hence very helpful in tracing the nerve. The reference point on the muscle also has an impact on the measurements. The nerve is also prone to distortion depending on the amount of traction applied on the tissues and even the positioning of the neck. For studies done during surgical procedures such as parotidectomies, pathologies such as tumours may apply tension on the nerve and cause some degree of distortion. These pathologic or surgical conditions may also affect the anatomy and configuration of soft tissue landmarks such as the PBDM.

The TMS though a hard tissue structure also exhibits varied dimensions with a range from 2.1mm to 10mm[12, 26]. This study found it at 5.81 mm from the FN trunk. The results of several studies showed that the nerve lies within 2.5, 6-8, 10 or 0.5-1 mm or 3 mm medial to, or deep to the end of the TMS [12, 26,28,29,30]. It is stated as being easily identifiable, its position is constant and its relation to the FN is reliable and allows for the nerve to be identified close to the foramen where it is least subject to displacement[30]. The TP has been described in some texts as the most reliable landmark in FN identification but from the studies reviewed, it demonstrates similar inconsistencies[31]. This study found the TP to have been 9.87+/-2.41mm from the FN trunk which was close to Nishanti et al. (2006) at 10.008+/-2.34mm. However, Rea et al. (2010) found a value of 6.9mm while Pather et al. (2006) found 3.4mm[12, 23, 26]. The TP has blunt and obtuse tips and different researchers use the different points of reference for the measurements[27, 29].

The distance between the FN trunk and the angle of the mandible was found to have been 37.98 mm which was similar to the report by Pather et al. (2006) 38.1mm, Davis et al. (1956) 32mm and McCormack et al. (1945) 34mm in Caucasians[8,12,14]. Asian studies reperted a shorter dimension with Myint et al. (1992) reporting 28.06mm and Park and Lee (1977) reporting 28.8mm [10, 22]. Myint et al. (1992) postulated that a longer distance between the bifurcation of the facial nerve and the angle of the mandible in Caucasians could be due to a larger stature, a bigger and stronger jaw or a combination of both factors in them when compared to Asians[22]. The racial difference between the Kenyan African and Asian population may be due to the larger stature of Kenyan Africans compared to Asians.

The most varied landmarks were the styloid process. The present study found it at 16.48 mm compared with Pather et al. (2006) who found it at 9.8mm[12.] This is attributed to its variations in anatomy[34]. The angle of the mandible is difficult to measure as it is blunt and rounded and, therefore, not easily reproducible. The most convex aspect- the gonion was selected but as a derived point, it is prone to errors in reproducibility. It had the widest range of 18- 45mm; Pather et al. (2006) in their study had an equally wide range of 25.3 to 48.69 mm[12].

There were no statistically significant differences in the comparison of these landmarks between the right and left sides. The gender distribution showed a slight increase in the distance of some of the landmarks although it was not statistically significant. This is in tandem with studies by Rea et al (2010), Kopuz et al. (1994) and Kalaycioglu et al.(2014) [9, 17, 26]. The slight increase in the morphometric parameters may be due to the difference in stature between the genders and hence the proportionate increase in these dimensions. However, there was correlation in some of the surgical landmarks between the left and right sides with the TP, TMS, EAM, PBDM and angle of the mandible having been significant. This can be of great importance during bilateral surgical procedures in locating the FN. Previous studies reviewed have not described these correlations

Standard deviations of these landmarks were compared and the more reliable were the TMS (1.28), PBDM (1.78) and TP (2.41). Less reliable landmarks were the styloid process (5.47) and angle of the mandible (4.45). The styloid process has an inconsistent anatomy in shape, size and curvature. It was also found to have been missing in 22.5% of this population hence it is most unreliable. It also lies in a plane deeper to the FN and, therefore, is of little help in identifying the nerve[31, 34]. This is in tandem with previous studies which have demonstrated a missing styloid process in up to 30% of the cases[27].A study by Rea et al. (2010) also found the TMS having been the most reliable landmark with a SD of 0.4 followed by TP 1.7, EAM 1.8 and PBDM 1.8 [26]. Nishanti found TP as the most reliable with a SD of 2.34, followed by the EAM 2.98 and TMJ 3.28 [23]. Pather et al. (2010) found the PBDM to have been the most reliable landmark with a SD of 0.31, followed by the TMS 0.38, EAM 0.35 and TP 0.67. These studies demonstrate wide ranges in some of the measurements indicating both reproducibility and reliability errors. Some researchers use the bifurcation point while others use the closest distance between the landmark and the nerve[27].

4.2 CONCLUSIONS

The current study establishes variations of anatomical patterns of the extratemporal FN in a black Kenyan population. It has shown that type I according to Davis et al. (1956) classification [8] branching pattern is the commonest. In addition, the TMS and PBDM were the most accurate landmarks in FN trunk identification.

4.3 RECOMMENDATIONS

The study recommends that the TMS and PBDM can be used as landmarks for identification of the FN during surgery.

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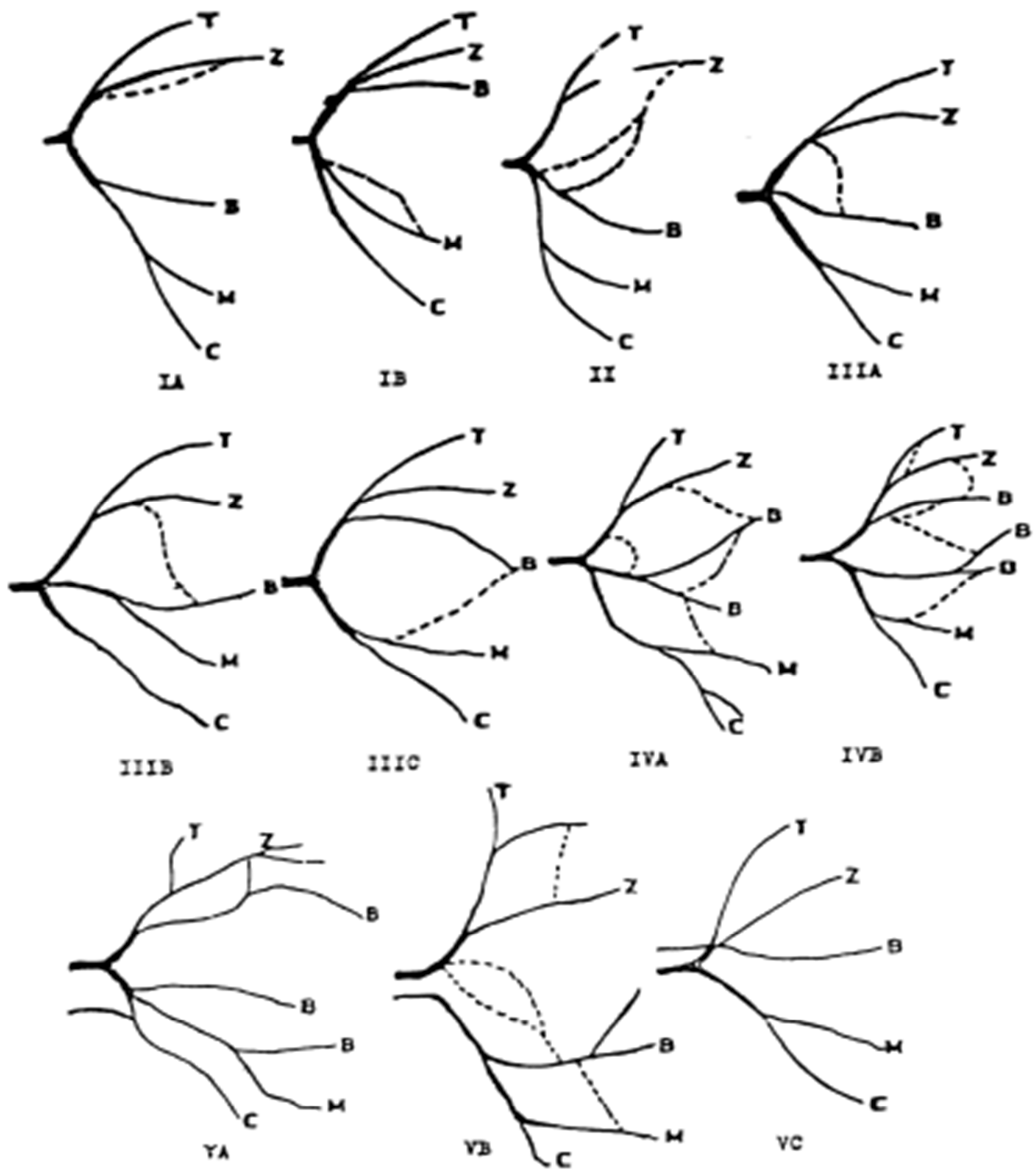
Appendix 1



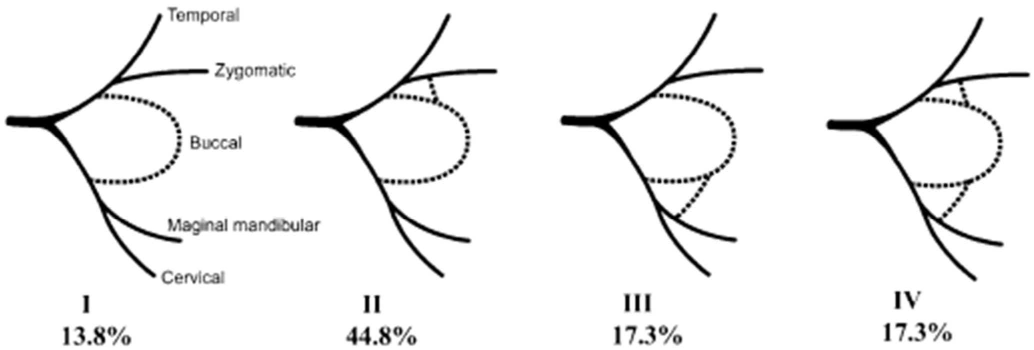
Classification of FN branching pattern based on main trunk by Katz & Catalano[11].

Appendix 2

Comparison of FN branching patterns according to Katz & Catalano[11] classification[9]

	(%) frequency	
Type	Katz & catalano[11](n=100)	Kopuz et al[9](n=50)
I	24	24
II	14	12
III	44	14
IV	14	38
V	3	12
Total	100	100

Appendix 3



Categories of the branching patterns of the FN according to the origin of the buccal branch by Kwak et al[5].

Appendix 4

Data collection chart

Index number:_____

Right		Left	

Gender: M F

Side	Right	Left
Branching pattern(Davis et al classification I-VI)		
Bifurcation of main trunk		
Length of trunk(mm)		
Distance of trunk from (mm)		
i. Tragal pointer		
ii. Tympanomastoid suture		
iii. External auditory meatus		
iv. Posterior belly of digastric		
v. Styloid process		
vi. Temporomandibular joint		
vii. Angle of mandible		

Appendix 5

PARTICIPANT INFORMATION AND CONSENT FORM

ADULT CONSENT

FOR ENROLLMENT IN THE STUDY

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Fax: 725272
Telegrams: MEDSUP, Nairobi

Title of Study: Extracranial facial nerve anatomical pattern variations in a Kenyan population

Principal Investigator: Dr Mutahi Francis Thuku

Institutional affiliation: University of Nairobi

Introduction:

I would like to tell you about a study being conducted by above researcher. The purpose of this consent form is to give you information to help you decide whether or not to give consent as next of kin to perform the study on the deceased. Please feel free to ask any questions about the purpose of the research, what happens to the deceased in the study and possible risks or benefits. When we have answered all questions to your satisfaction, you may decide to give consent to the study or not. This process is called 'informed consent'. We will give you a copy of this form for your records.

May I continue? YES/NO

The study has an ERC approval……………………………………

WHAT IS THIS STUDY ABOUT

The researchers will be examining facial nerve in the deceased during post mortem .The purpose of this study is to establish variations of facial nerve pattern among Kenyans. Limited studies have been done on African population and none so far on the Kenyan population. There will be approximately forty participants in this study randomly chosen. We are asking for your consent to consider participating in this study.

WHAT WILL HAPPEN IF YOU GIVE CONSENT TO THE STUDY

If you agree to participate in this study, the following things will happen:

In order to carry out the study, access to the facial nerve is required. In agreeing, a conservative incision around the side of the face and neck is required; dissection to expose the nerve and various measurements and digital photographs of the nerve will be taken. The tissues will be placed back to close to original position as possible and the incision will then be stitched appropriately. No specimen will be taken from the body.

ARE THERE ANY RISKS, DISCOMFORTS ASSOCIATED WITH THIS STUDY?

One potential risk of being in the study is loss of privacy. We will keep everything we obtain be it in form of data or photographs as confidential as possible. We will use a code number to identify you in a password-protected computer database and will keep all of our paper records in a locked file cabinet. Upon completion of the study, the data both hard and softcopies will be destroyed. However, no system of protecting your confidentiality can be completely secure so it is still possible that someone could find out you were in this study and could find out information about the deceased.

The study will involve making an extra incision around the side of face not routinely done during autopsies. This may lead to some minor distortion of the area being studied. However no specimen will be collected and all tissues will be left in the body.

ARE THERE ANY BENEFITS BEING IN THIS STUDY?

The information gathered here will bridge knowledge gap in the Kenyan population about facial nerve, and also assist in conducting surgeries of the facial region and reduce facial nerve injuries during surgery.

Participation in this study will not result in any financial benefits.

The information obtained may be used in improving surgical treatment in patients presenting with diseases, trauma or deformities of the head and neck region.

WILL BEING IN THIS STUDY COST YOU ANYTHING?

No, the study will not cost you anything.

WHAT IF YOU HAVE QUESTIONS IN FUTURE?

If you have further questions or concerns about participating, please call or send a send a text message to the study staff at the number provided at the bottom of this page.

For more information about the rights of the deceased as a research participant you may contact the Chairperson, Kenyatta National Hospital/University of Nairobi Research and Ethics Committee, Prof. A.N Guantai at Tel No.2726300 ext. 44355/44102.

The study staff will pay you back for your charges to these numbers if the call is for study-related communication.

WHAT ARE YOUR OTHER CHOICES?

Your decision to allow the deceased participate in research is voluntary. You are free to decline participation in the study and you can withdraw the deceased from the study at any time without injustice or loss of any benefits.

1. Dr Francis Thuku Mutahi (investigator): cell 0723297126, email thukufrancis@yahoo.com

2. Dr Fawzia Butt (supervisor) cell 0722703347, email fawziamaxfax@gmail.com

3. Kenyatta national hospital/ university of Nairobi ethics and research committee, P.O. Box 20723, tel 726300-9, email KNHplan@ken.healthnet.org

CONSENT FORM

Next of kin statement

I have read this consent form. I have had the chance to discuss this research study with a study counselor. I have had my questions answered in a language that I understand. The risks and benefits have been explained to me. I understand that participation in this study is voluntary and that I may choose to withdraw assent for deceased participation any time. I freely agree to allow the deceased be a participant in this research study.

I understand that all efforts will be made to keep information regarding personal identity of the deceased confidential.

By signing this consent form, I have not given up any of the legal rights of the deceased as a participant in a research study.

I agree to let deceased participate in this research study: Yes No

Next of kin signature / Thumb stamp ___________________________________

Date ___________________

Next of kin printed name: ____

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Kiswahili consent form

FOMU YA RIDHAA

Mada: Utafiti kuhusu nevi ya uso katika jamii ya Wakenya

Mtafiti mkuu: Francis Thuku Mutahi

Taasisi ya utafiti: Chuo Kikuu cha Nairobi

Utambulisho:

Ningependa kukuelezea kuhusu utafiti unaofanywa na waliotajwa hapo juu. Lengo la fomu hii ya ridhaa ni kukufahamisha yale utakayohitajika kujua ili kukusaidia kuamua kutoa ridhaa kwa mwili wa marehemu kushiriki katika utafiti huu. Unaweza kuuliza maswali kuhusu yale utakayohitajika kufanya, athari zozote, manufaa zozote na haki zako kama mshirika.

Unaporidhika na majibu unaweza kuamua kushiriki au kutoshiriki katika utafiti huu. Hii inaitwa ridhaa ya kujua. Tutakupa nakala ya fomu hii ili ujiweke.je, ninaweza kuendelea?

NDIO/ LA

Utafiti huu umekubaliwa na ERC ______________________

UTAFITI HUU UNAHUSU NINI?

Watafiti waliotajwa hapo juu wanafanya utafiti maumbile tofauti tofauti ya nevi ya uso katikati ya WaKenya. Ni utafiti unaofanywa kwa wafu wakati wa upasuaji wa kuelezea kiiini cha kifo.

Kutakuwa na washirika takriban 40 katika utafiti huu, wote watakaochaguliwa bila kufuata muundo wowote. Hili ni ombi kwako ukubali kushiriki katika utafiti huu.

TARATIBU ZITAKAZOFUATWA ENDAPO UTAKUBALI KUSHIRIKI KATIKA UTAFITI HUU

Endapo utakubali kushiriki kwenya utafiti huu, yafuatayo yatafanyika kwa mwili wa marehemu

Wakati wa upasuaji kujua kiini ya maafa, tutafanya upasuaji kidogo wa uso ili kufuatilia chanzo cha, ugawanyifu, vipimo vya urefu vya hii nevi kwa shingo na uso. Kisha tutachukua picha ya hiyo nevi hiyo na hatimaye tutashona mahali hapo kwa utaratibu ili pasionekane lawama lolote. Hakuna sampuli yoyote tutachukua katika mwili wa marehemu na kila kitu tutarejesha vile vile.

JE KUNA MAADHARA, MATATIZO NA ADHA ZOZOTE KUHUSU UTAFITI HUU?

Tatizo moja linaloweza kutokea ni kutokuwa na siri ya habari. Tutahakikisha habari zote zinazopatikana wakati wa mahojiano zitahifadhiwa vyema na kwa siri. Tutatumia kodi kukuwakilisha katika kompyuta iliyohifadhiwa na neno kificho na karatasi zote zinahifadhiwa wema kwa kufungwa mbali. Hata hivyo hatuwezi sema tutaweza kuficha habari kabisa kwa hivyo ushirikiano wako katika utafiti huu bado unaweza kugunduliwa na mtu.

JE KUNA FAIDA ZOZOTE ZA KUSHIRIKI KWENYE UTAFITI HUU?

Endapo utakubali marehemu kushiriki kwenye utafiti huu, hakuna faida yoyote ya kibinafsi. habari zenye utatuelezea zitatusaidia kufahamu na kufanya upasuaji wa uso na shingo.

GHARAMA

Kushirikiana katika utafiti huu haitakuongezea gharama yoyote.

JE UTARUDISHWA PESA ZOZOTE UTAKAZOTUMIA KATIKA UTAFITI HUU?

Hakuna pesa zozote utapokea kwa kukabali marehemu kufanyiwa utafiti huu.

JE UTAKAPOKUWA NA MASWALI BAADAYE?

Utakapokuwa na maswali yoyote baadaye tafadhali pigia simu au kutuma ujumbe kwa namba iliyo hapo mwishowe.

Kwa mahojiano zaidi kuhusu haki zako kama mshiriki unaweza kuuliza mkuu wa Kamati ya Utafiti na Maadili ya Hospitali Kuu ya Kenyatta/ Chuo Kikuu cha Nairobi (KNH/UON Research and Ethics Committee), Prof. A.N. Guantai, namba ya simu 2726300 ext 44355/44102.

JE UNAWEZA KUFANYA LOLOTE LINGINE?

Uamuzi wakokupeana idhini mwili wa marehemu kushiriki katika utafiti huu ni kwa hiari yako. Unaweza kukataa idhini kushiriki au kujitoa wakati wowote bila kufanyiwa lolote.

1. Dr Francis Thuku Mutahi (mtafiti): nambari ya simu 0723297126, barua pepe thukufrancis@yahoo.com

2. Dr Fawzia Butt (msimamizi) nambari ya simu 0722703347, barua pepe fawziamaxfax@gmail.com

3. Kamati ya Utafiti na Maadili ya Hospitali Kuu ya Kenyatta/ Chuo Kikuu cha Nairobi (KNH/UON Research and Ethics Committee), anwani 20723, nambari ya simu 0726300-9, barua pepe KNHplan@ken.healthnet.org

FOMU YA RIDHAA

Tangazo la mshiriki

Nimesoma fomu hii ya ridhaa na nimeweza kuongea na mhoji/mtafiti kuihusu. Nimepata majibu ya maswali yangu katika lugha ninayofahamu sawasawa. Nimeelezwa manufaa na maadhara yote. Ninaelewa ushirikiano wa marehemu katika utafiti huu ni wa kujitolea na ninaweza kumwondoa wakati wowote. Ninakubali ashiriki katika utafiti huu.

Ninaelewa mtajaribu kuhifadhi habari za marehemu na zozote zingine ziwe siri.

Kwa kuweka sahihi katika fomu hii, sijawachilia haki za marehemu kama mshirika katika utafiti.

Ninakubali marehemu kushiriki katika utafiti huu. Ndio la

Nimekubali kupeana namba yangu ya simu kutumiwa ikiwa kuna jambo lolote la kuulizia baadaye. Ndio la

Sahihi ya ndugu ya marehemu/ alama ya kidole

____

Tarehe :_________________________

Jina la ndugu wa marehemu : ____________________________

Tangazo la mtafiti

Mimi mtafiti nimemwelezea mshiriki mambo yote kuhusu utafiti huu. Mshiriki aliyetajwa hapo juu na amefahamu mambo yote na kujitolea hiari ili marehemu awe mshiriki katika utafiti huu.

Jina la mtafiti: ________________________________

Tarehe :_________________________

Sahihi ya mtafiti_________________________________

Wajibu katika utafiti :_____________________________

Kwa habari zozote zaidi tafadhali ongea na Dr. Francis Thuku aliye katika Chuo Kikuu cha Nairobi/ Hospitali kuu ya Kenyatta, namba ya simu +25473297126 kati ya saa mbili asubuhi na saa kumi na moja jioni.

Jina la shahidi (kuchapishwa) ....

Jina _________________________________

Namba ya simu ________________________

Sahihi / alama ya kidole :______________________________________

Tarehe : ______________________________

Appendix 6

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Ref: KNH-ERC/A/185

22nd April, 2015

KENYATTA NATIONAL HOSPITAL APPROVED 22 APR 2015 KNH/UoN-ERC P.O. Box 20723-00202 NRB.

Francis Mutahi Thuku
Dept of Oral and Maxillofacial Surgery
School of Dental Sciences
University of Nairobi

Dear Francis

Research Proposal: Extracranial facial Nerve Anatomic Pattern variations in a Kenyan Population (P112/03/2015)

This is to inform you that the KNH/UoN-Ethics & Research Committee (KNH/UoN-ERC) has reviewed and **approved** your above proposal. The approval periods are 22nd April 2015 to 21st April 2016.

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc) are submitted for review and approval by KNH/UoN ERC before implementation.
c) Death and life threatening problems and severe adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH/UoN ERC within 72 hours of notification.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH/UoN ERC within 72 hours.
e) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
f) Clearance for export of biological specimens must be obtained from KNH/UoN-Ethics & Research Committee for each batch of shipment.
g) Submission of an *executive summary* report within 90 days upon completion of the study
This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/or plagiarism.

For more details consult the KNH/UoN ERC website **www.erc.uonbi.ac.ke**

Yours sincerely,

PROF. M. L. CHINDIA
SECRETARY, KNH/UON-ERC

c.c. The Principal, College of Health Sciences, UoN
The Deputy Director CS, KNH
The Chair, KNH/UoN-ERC
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