SURGICAL ANATOMY OF MEDIAN NERVE AT THE CARPAL TUNNEL IN ADULT BLACK KENYAN POPULATION: A CADAVERIC STUDY

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A RESEARCH THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF MEDICINE IN ORTHOPAEDIC SURGERY, MOI UNIVERSITY.

DECLARATION

Declaration by the student

The candidate declares that the Thesis is original and personal work and has not been presented in any another University for any award.

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DEDICATION

The candidate dedicates this Thesis to his family for their value of academic knowledge and the support throughout the entire period of the study.

DISCLOSURE

The candidate did not receive any external funding or grants in support for the study.

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ABSTRACT

Background: The median nerve, a branch of brachial plexus in the upper limb, is at risk of injury at the carpal tunnel during wrist surgeries. Several studies have been conducted on the variations of median nerve in the carpal tunnel but there is no regional or local published data. Knowledge of anatomical variations of the median nerve at the wrist is important in repair of traumatic injuries and treatment of carpal tunnel syndrome as these situations require precise dissection of the nerve and such variations and injuries are not uncommon.

Objective: To describe the variations in the course and distribution of the median nerve and its branches in the carpal tunnel in an adult black Kenyan population.

Methods: The study conducted at the Human Anatomy Laboratory of Moi University School of Medicine, Eldoret using anatomical cross sectional design. A census of fifty six left upper limbs that met the inclusion criteria were dissected according to the techniques described by The Cunningham's Manual of Practical Anatomy 16th Edition. The course and distribution of the median nerve and its branches in the carpal tunnel were described and photographs taken. The distal wrist crease and longitudinal axis of hand were taken as reference points. Data was recorded in data collection sheets and fed into electronic database with restricted access. Data analysis done using STATA version 13SE. Results were presented using tables and box plots.

Results: Median nerve passed deep to the flexor retinaculum (FR) in all the specimens. Its location was mostly on the radial side (78.57%) of the carpal tunnel. The level of division was distal to FR in 76.79%, within in 14.28% and proximal in 8.93%. Persistent median artery was present in 3.57%. The thenar motor branch (TMB) arose from the lateral branch in 76.79% of the cases. The course of the TMB was extraligamentous in 76.79% and subligamentous in 23.21%. The TMB supplied all the 3 thenar muscles in 82.14% and only the Abductor Pollicis Brevis and Opponens Pollicis in 17.86%. Accessory thenar branches distal to FR were present in 12.5% of cases. The TMB was located 32.46 ± 4.03mm from the distal wrist crease (DWC). The TMB terminated 8.85 ± 1.59mm to the radial side of the longitudinal axis of the hand.

Conclusion: The course and distribution of the median nerve at the carpal tunnel is variable and was found to be similar to the findings in most of the previous studies. There was radial sided dominance of median nerve course. The TMB was located in an area defined by 32.46 ± 4.03 mm from the DWC and 8.85 ± 1.59 mm to the radial side of the longitudinal axis of the hand.

Recommendations: Surgeons should be aware of the variations in the course and distribution of median nerve at carpal tunnel and take extra care in high risk areas where TMB is located. Ulnar sided incisions of the transverse carpal ligament is upheld.

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LIST OF ABBREVIATIONS AND ACRONYMS

APB	Abductor Pollicis Brevis
CTS	Carpal Tunnel Syndrome
ECTR	Endoscopic Carpal Tunnel Release
FPB	Flexor Pollicis Brevis
FR	Flexor Retinaculum
IREC	Institutional Research and Ethics Committee
IQR	Inter Quartile Range
MTRH	Moi Teaching and Referral Hospital
OCTR	Open Carpal Tunnel Release
OP	Opponens Pollicis
ORIF	Open Reduction and Internal Fixation
PCTR	Percutaneous Carpal Tunnel Release
PMA	Persistent Median Artery
TMB	Thenar Motor Branch

OPERATIONAL DEFINITIONS OF VARIABLES AND KEY TERMS

Adult: A person who is aged 18 years and above.

Carpal tunnel: The space between the flexor retinaculum of the wrist and the carpal bones where the median nerve and the flexor tendons of the fingers and thumb pass through.

Course: The route or direction followed by a nerve.

Distribution: The area supplied by a nerve.

Variation: Difference in the usual form or arrangement.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

The median nerve is one of the terminal branches of the brachial plexus formed by the convergence of the medial and lateral cords. It has contributions from all the anterior rami of C5-T1. It is a mixed motor and sensory nerve. The median nerve supplies the flexor muscles of the forearm and hand as well as the thenar muscles of the thumb. It also provides sensory innervations to the lateral two thirds of the palm and the palmar surface of the lateral three and half fingers and the back of their distal phalanges (Standring, 2016).

At the wrist, the median nerve enters the carpal tunnel deep to the flexor retinaculum and reaches the palm beyond the distal border of flexor retinaculum together with the four tendons of the flexor digitorum superficialis, the four tendons of the flexor digitorum profundus and the tendon of the flexor pollicis longus. This highly crowded area, the carpal tunnel, is a prime spot for compression. Carpal Tunnel Syndrome is the most well-known and frequent form of median nerve entrapment, and accounts for 90% of all entrapment neuropathies (Keith, et al., 2010).

Numerous anatomical variations along the course of the median nerve and its branches in the carpal tunnel have been reported. The variations along the course of the thenar motor branch (TMB) have been described in many of the previous studies using the Poisel’s classification system (Henry, et al., 2015). Poisel, (1974) described three types of TMB branching: extraligamentous (Type I), subligamentous (Type II), and transligamentous (Type III). He reported the extraligamentous type as the most common.

Lanz, (1977) expanded Poisel's classification system to include variations of the median nerve in the carpal tunnel. He described four groups of TMB variations: variations in the course of the single TMB according to Poisel (Group I), accessory branches of the median nerve at the distal carpal tunnel (Group II), high division of the median nerve (Group III), which Lanz reported to be associated with the presence of a persistent median artery (PMA) running with the bifid median nerve, and accessory branches of median nerve proximal to the carpal tunnel (Group IV). Lanz’s drawings have been used in most studies to describe the variations in median nerve at the carpal tunnel (Figure 1).

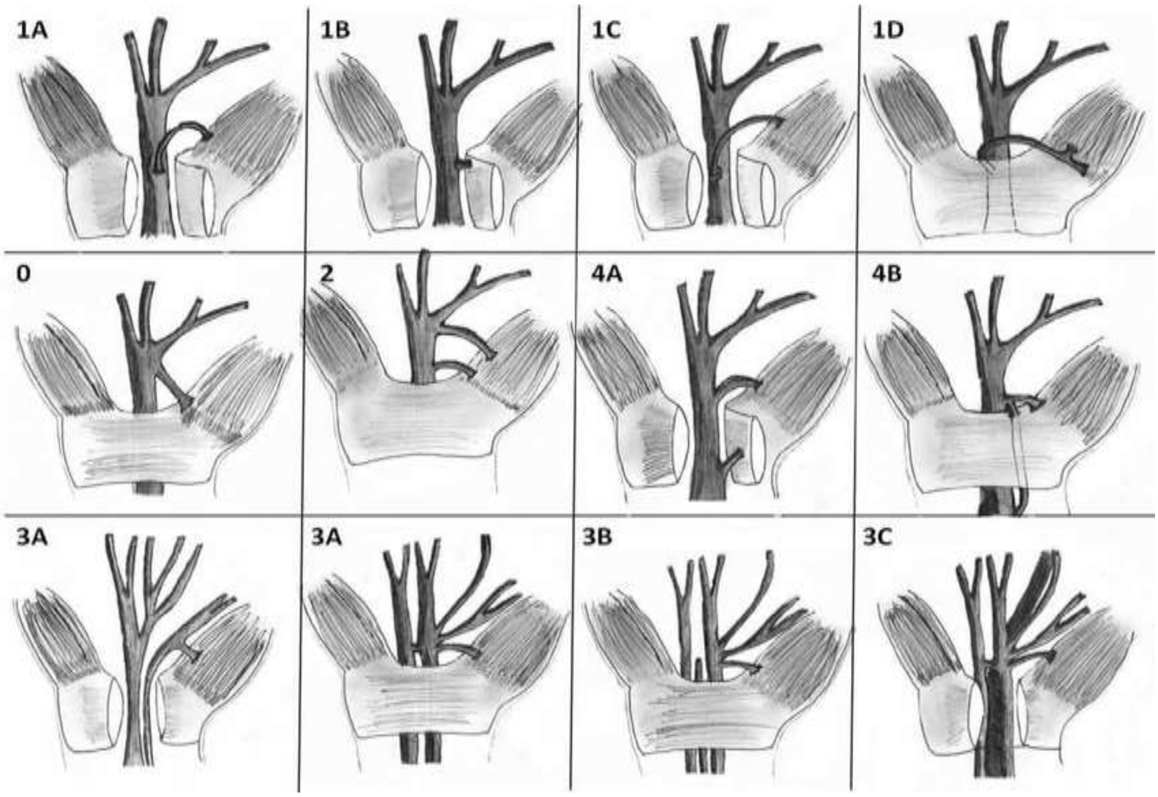

Figure 1: Lanz classification of median nerve variations at the carpal tunnel. Adopted from Lanz, 1977.

1.2 Problem statement

Wrist and hand injuries are the most frequent trauma cases at MTRH. With them are associated median nerve injuries though they are under-reported as more focus is given to fractures and tendon injuries.

Repair of flexor tendon injuries and fractures around the wrist involves dissection and splitting of flexor retinaculum and may pose a risk to structures in the carpal tunnel most importantly the median nerve and its branches. Injury to the motor branch of the median nerve is one of the devastating documented complications of the volar approaches to the wrist and hand. The TMB has been named the "million dollar nerve" due to high legal costs incurred by surgeons upon accidental damage to the nerve during surgical procedures

The course and distribution of median nerve at carpal tunnel is highly variable. Cheruiyot, et al., (2017) in their study of median arteries in adult black Kenyans found a high prevalence of variations than that reported in literature in branching pattern of median arteries with a mention of it piercing median nerve in 18.9 % of the cases.

1.3 Justification

The variable course and distribution of the median nerve and its branches at the carpal tunnel presents a possibility of injury during surgery. Such injuries can be prevented by reliable anatomical knowledge of the relationship of the median nerve and its branches to the flexor retinaculum and its common patterns of variation at the carpal tunnel. This study will provide morphometric data that could be applied during surgical procedures (both preoperatively and intraoperatively) around the carpal tunnel thereby reducing the occurrence of iatrogenic median nerve injuries.

Population specific data are critical in guiding surgery. Caucasians and Asian subjects have been studied and differences in median nerve variations have been found in these populations (Henry, et al., 2015). Variability in the course and distribution of the median nerve and its branches at the carpal tunnel is currently unknown among black Kenyans as most studies are from the western world. This study will therefore serve as a baseline for development of other subsequent related studies.

This study will provide easy and reliable surgical landmarks to demarcate safe zones to surgeons operating on adult black Kenyans wrists. This has to be applied during surgical approaches at the wrist to avoid or minimize injury to the median nerve during wrist surgeries

1.4 Research question

What are the variations in the course and distribution of the median nerve and its branches at the carpal tunnel in adult black Kenyan population?

1.5 Research Objectives

1.5.1 Broad objective

To describe the variations in the course and distribution of the median nerve and its branches at the carpal tunnel in adult black Kenyan population.

1.5.2 Specific objectives

1. To describe the course of main trunk of median nerve at the carpal tunnel in adult black Kenyan population.
2. To describe the pattern of division of the main trunk of the median nerve and its main branches (medial and lateral) at the carpal tunnel in adult black Kenyan population.
3. To describe the origin, course, and distribution of the thenar motor branch of median nerve at the carpal tunnel in adult black Kenyan population.
4. To describe the topographical localization of median nerve and its main branches at the carpal tunnel in adult black Kenyan population.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Anatomy of the median nerve

2.1.1 Origin

The median nerve is one of the terminal branches of the brachial plexus formed by the convergence of the medial and lateral cords. The lateral root (C5, 6, 7) is derived from the lateral cord while the medial root (C8, T1) is derived from the medial cord of the brachial plexus. The medial root crosses in front or sometimes behind the third part of axillary artery at the lower border of pectoralis minor muscle to join the lateral root on the lateral side of the third part of axillary artery (Standring, 2016)

2.1.2 Course and relations

The median nerve descends lateral to the third part of axillary artery and upper half of brachial artery. In the middle of the arm it crosses in front of the brachial artery to descend medial to the artery along the lower half of the arm down to the cubital fossa.

The median nerve enters the forearm by passing between the two heads of pronator teres muscle then the nerve descends close to the deep surface of the flexor digitorum superficialis adherent to the fascia of the muscle. Two inches above the wrist, the median nerve winds around the lateral side of the tendons of the flexor digitorum superficialis and medial to the tendon of flexor carpi radialis concealed by the tendon of palmaris longus to become superficial.

The median nerve enters the palm of the hand by passing deep to the flexor retinaculum (carpal tunnel). Just distal to the flexor retinaculum the median nerve ends by dividing into lateral and medial terminal divisions (Standring, 2016)

2.1.3 Branches in the hand

The lateral branch gives off the thenar motor branch which supplies the thenar muscles of the hand: flexor pollicis brevis, abductor pollicis brevis, and opponens pollicis.

The lateral branch then subdivides into three proper palmar digital nerves to supply the two sides of the thumb and radial side of the index finger. The branch to the index finger provides a branch to the first lumbrical.

The medial branch subdivides into two common palmar digital nerves, lateral and medial. The lateral common nerve gives a branch to the second lumbrical and subdivides to supply the adjacent sides of the index and middle finger. The medial common nerve receives a communicating branch from the superficial branch of the ulnar nerve and then subdivides to supply the adjacent sides of the middle and ring finger (Standring 2016)

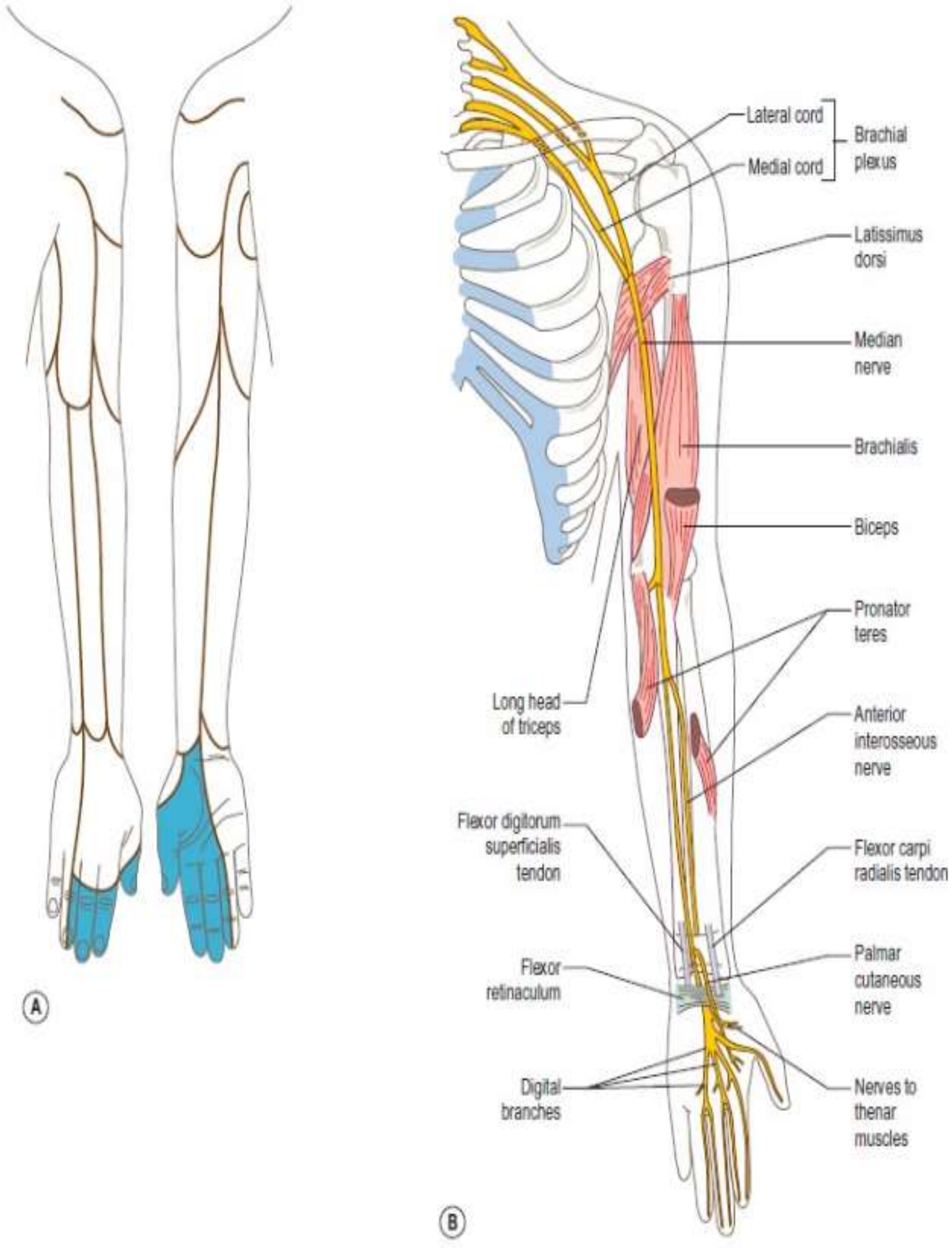

Figure 2: The anatomy of the median nerve.
(https://www.raynersmale.com/blog/2016/7/30/carpal-tunnel-syndrome)

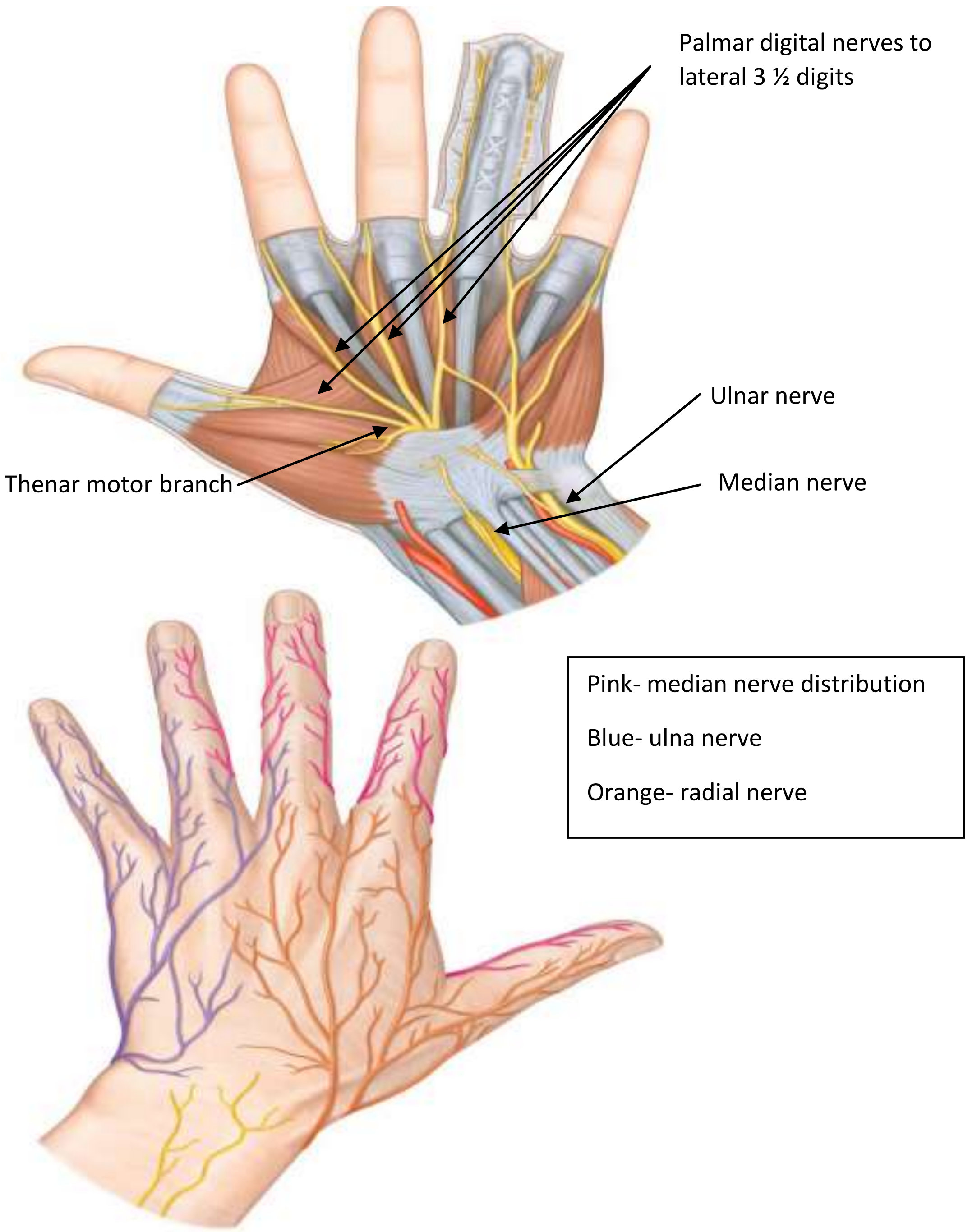

Figure 3: The division and distribution of median nerve. Adopted from Standring, 2008.

2.2 Surgical anatomy of the carpal tunnel

The flexor retinaculum is a thick and strong fibrous band which bridges over the carpal groove thus converting the groove into an osseo-fibrous tunnel called the carpal tunnel. Its main function is to serve as a flexor pulley at the wrist for the flexor tendons. The retinaculum is attached medially to the pisiform and hook of hamate and laterally to the tubercle of scaphoid and the crest of the trapezium. The carpal tunnel is a narrow fibro-osseous tunnel through which the median nerve passes with nine tendons and their synovial sheaths (four tendons of Flexor Digitorum Superficialis, four tendons of Flexor Digitorum Profundus and one tendon of Flexor Pollicis Longus) (Standring, 2016).

Carpal tunnel syndrome

Carpal Tunnel Syndrome (CTS) is a disabling condition commonly presented to Orthopaedic Hand surgeons. The American Academy of Orthopaedic Surgeons (AAOS) Clinical Guidelines on the Diagnosis of CTS defines it as a symptomatic compression neuropathy of the median nerve at the level of the wrist. CTS is the most common form of median nerve entrapment, accounting for 90% of all entrapment neuropathies (Keith, et al.,2010)

The main presenting signs of CTS is pain in the hand, unpleasant sensation or numbness in the distal distribution of the median nerve (lateral three and half fingers) and a reduction of the grip strength and function of the affected hand (Zyluk and Kosovets, 2010).

The treatment of CTS can either be non-operative or operative. Non-operative treatment is generally offered to patients suffering from mild to moderate symptoms of CTS. Non-operative treatment options include oral and intravenous steroids, corticosteroids, vitamins B6 and B12 (Sato, et al., 2005), nonsteroidal anti-inflammatory drug (NSAIDs), and the use of hand splints.

Operative treatment of CTS is in the form of a carpal tunnel release (CTR); a procedure in which the flexor retinaculum is cut to increase the space in the carpal tunnel and hence reduce the interstitial pressure. Approximately 70-90% of patients have good to excellent long-term outcomes following CTR (Scholten, et al., 2007).

Complication rates for both open (OCTR) and endoscopic carpal tunnel release (ECTR) procedures are usually low. Many of the potential complications that occur during CTR surgery can be avoided if the surgeon has a good grasp of the anatomy of the carpal tunnel and its possible anomalies.

Ultrasound guided percutaneous carpal tunnel release incorporates the careful delineation of the thenar motor branch of the median nerve, for instance, which may help reduce the risk of complications due to nerve damage (Tagliafico et al., 2008).

Palmer and Toivonen, (1999) surveyed 708 hand surgeries done by members of the American Society for Surgery of the Hand and they reported 450 surgically treated complications of endoscopic and open CTR over a 5-year period, which included 121 vessel lacerations, 100 median nerve lacerations, 88 ulnar nerve lacerations, 77 digital nerve lacerations, and 69 tendon lacerations. Although this was a retrospective voluntary study with resultant methodologic flaws, the data support the conclusion that carpal tunnel release, be it endoscopic or open, is not a safe and simple procedure.

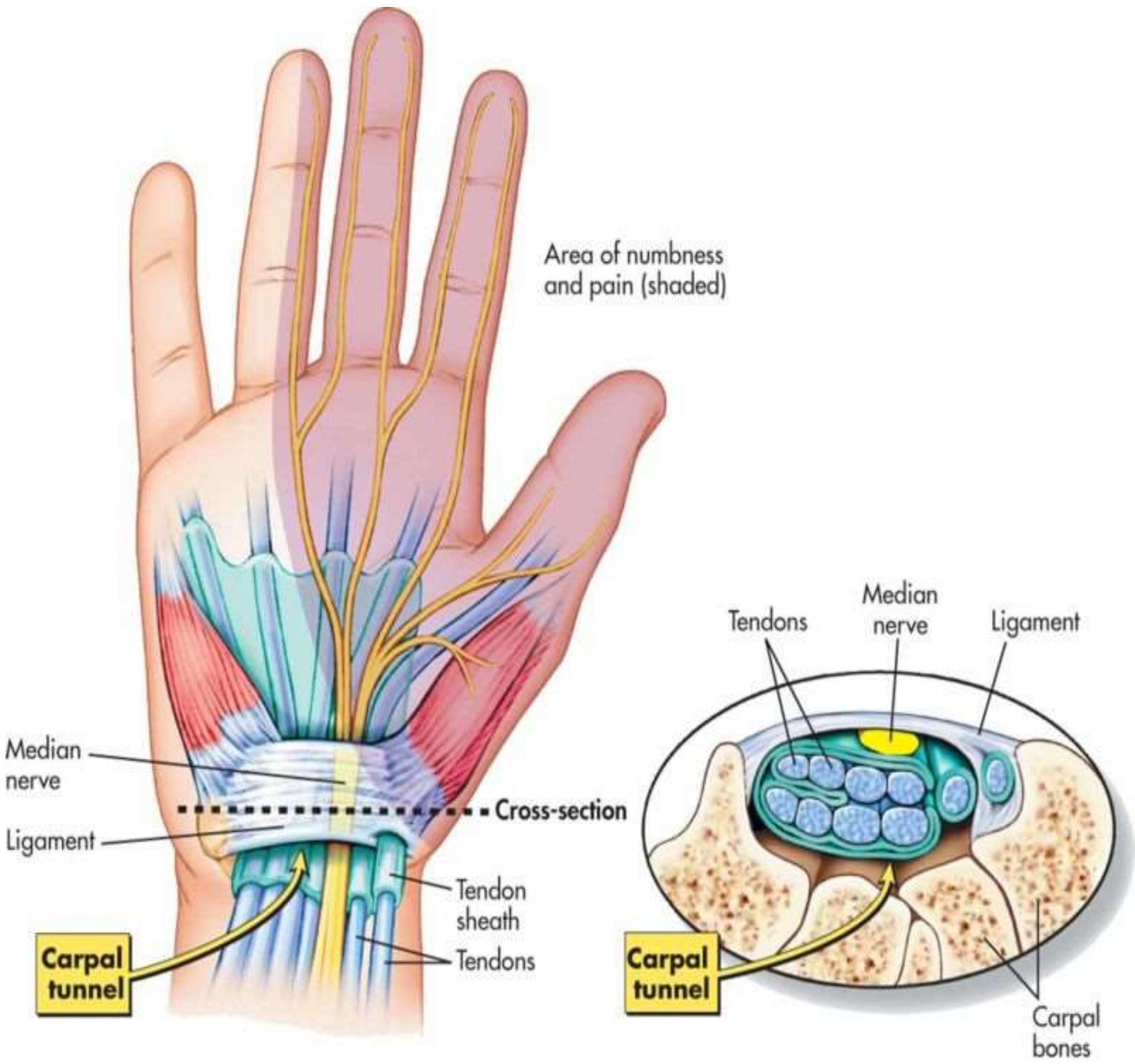

Figure 4: The surgical anatomy of the carpal tunnel.
(https://physiolounge.co.uk/can-physio-help-carpal-tunnel-syndrome/)

2.3 Volar approach to the wrist

Indications

- Decompression of median nerve
- Flexor tendon synovectomy
- Carpal tunnel tumor excision
- Carpal tunnel nerve and tendon repair
- Drainage of sepsis tracking up from the mid-palmar space
- Open Reduction and Internal Fixation (ORIF) of fractures and dislocations of distal radius and carpus

Procedure

The patient under local or regional anaesthesia is placed supine on table then the operative arm is supinated and placed on an arm board with palm facing up and a tourniquet applied to exsanguinate the arm. An incision is made just ulnar to the thenar crease in hand and ulnar to palmaris longus in wrist. The incision begins 4cm distal to flexion crease and ends 3 cm proximal to flexion crease. Skin flaps are raised and fat incised. Fibers of the superficial palmar fascia are sectioned in line with the incision. The curved flaps are retracted medially to expose insertion of the palmaris longus tendon into the flexor retinaculum. The palmaris longus tendon is retracted toward the ulna to expose the median nerve under the palmaris longus and Flexor Carpi Radialis. A blunt object is passed between the median nerve and retinaculum. The entire length of the retinaculum is incised on ulnar side of the nerve distally and proximally. The thenar motor branch of median nerve is identified (antero-lateral side of median nerve as it emerges from carpal tunnel). If access to volar aspect of wrist joint is required then mobilize median nerve and retract radially (so you do not stretch motor branch), mobilize and retract flexor tendons and incise base of carpal tunnel longitudinally.

Dangers

1. Palmar cutaneous branch of median nerve-arises 5 cm proximal to wrist joint and runs ulnar to flexor carpi radialis before crossing flexor retinaculum.
2. Motor branch of median nerve- significant anatomic variation. Risk to nerve minimized if incision through retinaculum made ulnar to median nerve
3. Superficial palmar arch - crosses palm at level of distal end of outstretched thumb. In danger if flexor retinaculum blindly cut (can go too far distally). Avoid injury if retinaculum cut under direct observation for its entire length

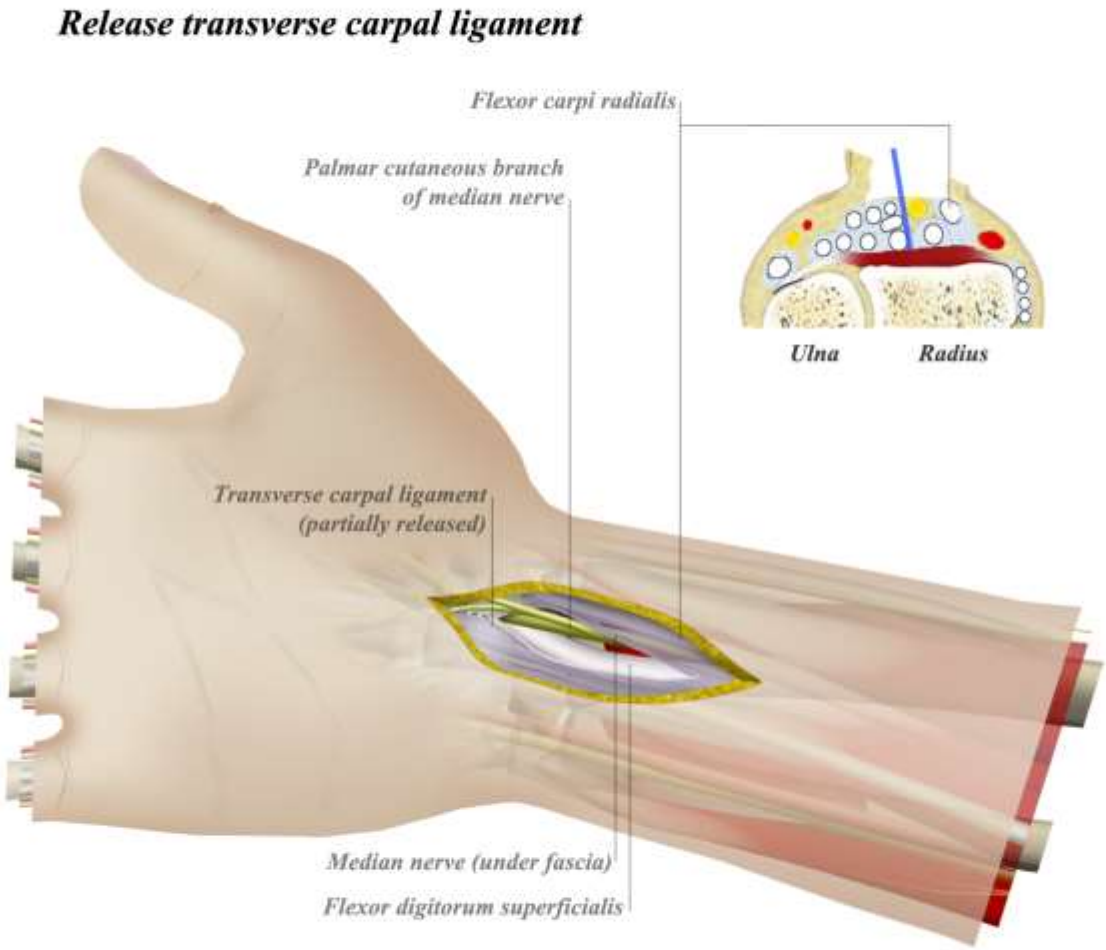

Figure 5: Volar approach to the wrist
(https://www.orthobullets.com/approaches/12014/volar-approach-to-wrist)

2.4 Anatomic variations of median nerve at the carpal tunnel

Median nerve variations are well described in literature due to its diagnostic and surgical importance (Alizadeh, et al., 2006; Falconer & Spinner, 1985; Lanz Ulrich, 1977)

Lanz, (1977) classified the variations in the course of the median nerve into four groups (Table 1). Group I is further sub-divided into four groups. Group IA, the motor branch of the median nerve starts beneath the transverse ligament and then bends around its distal edge (subligamentous). Group IB, the motor branch originates from the radial side of the median nerve and then passes through the transverse ligament (transligamentous). Group IC, the motor branch arises from the ulnar side of the median nerve. Group ID, the motor branch bends around the distal edge of the ligament (supraligamentous). The transligamentous course is of great clinical significance because of the possibility of compression within the retinacular fibers(Johnson & Shrewsbury, 1970).

Group II are Accessory branches of the median nerve at the distal portion of the carpal tunnel

Group III is divided into three subgroups according to the absence (Group III A) or the presence of a persistent median artery (Group IIIB) or an accessory lumbrical muscle (Group IIIC) between the two branches of the proximally divided median nerve.

There are accessory branches leaving median nerve proximal to the carpal tunnel in Group IV. Accessory thenar branch may run directly in the thenar muscles (Group IVA), or it may join another motor branch first (Group IVB).

Table 1: Lanz classification of median nerve variations in carpal tunnel

Group	Description
0	Extraligamentous thenar branch (standard anatomy)
I	Variations in the course of the thenar branch
II	Accessory branches of the median nerve at the distal portion of the carpal tunnel
III	High divisions of the median nerve
IV	Accessory branches proximal to the carpal tunnel

Course of main trunk of median nerve

Apart from its relations, most anatomical text books do not give further description of the course of the main trunk of the median nerve as it passes through the carpal tunnel. The position and course of the median nerve within the carpal tunnel shows some variations in relation to the longitudinal axis of the hand. Schmidt, (2007) described that the nerve passes dorsal to the flexor retinaculum to the palm without curving in two thirds of the cases. When it does not curve, the median nerve is shifted to the radial side of the carpal tunnel in 43.3%, below the middle of the flexor retinaculum in 21.7% and to the ulnar side in 1.7%. Median nerve curves within the carpal tunnel diverging to the radial in 21.6% of the cases and to the ulnar side in 11.7% of the cases.

Sanmugalingam, et al., (2020) gave a quantitative description of the position of median nerve at carpal tunnel. They measured the distance from hook of hamate and tubercle of trapezium to the median nerve on MRI. They found a radial sided dominant position of median nerve.

The position of the median nerve at the carpal tunnel is surgically relevant during carpal tunnel surgery which involves splitting of transverse carpal ligament, as there has been debate about the optimal approach of the incision. Boughton, et al., (2010) suggested a 3^{rd} web space axis approach while Samarakoon, et al., (2014) suggested the radial border of ring finger approach which may provide better and safer access to the median nerve. Wheatley, (1996) and Hong, et al., (2006) suggested the ulnar ring finger approach though this may increase risk of injury to ulna artery.

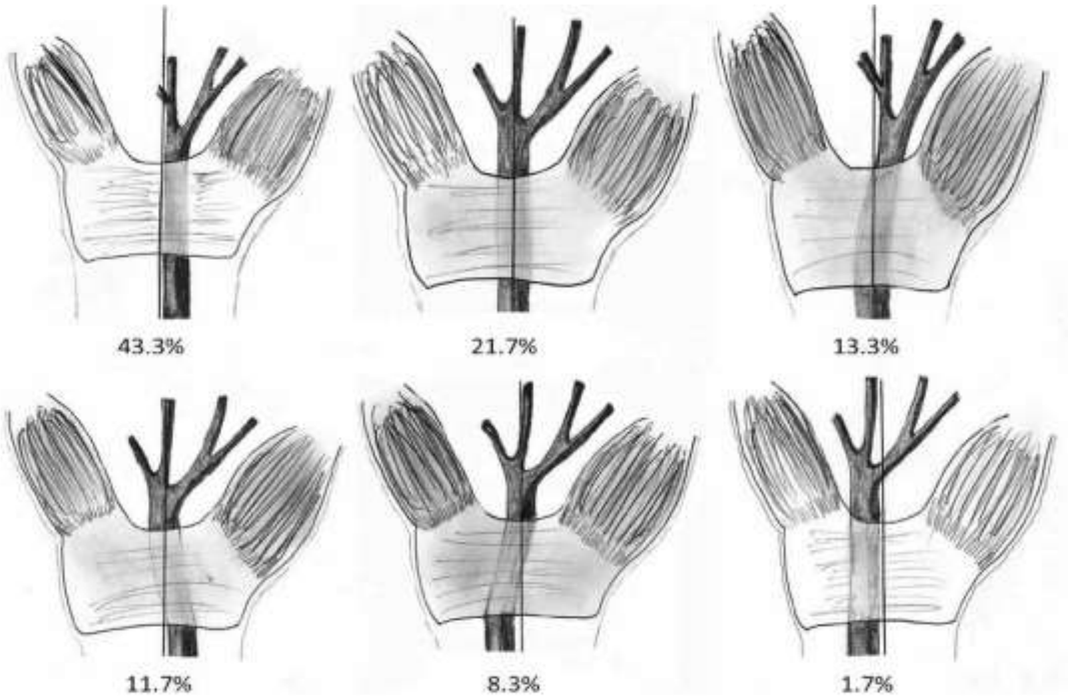

Figure 6: Variations in the course and position of median nerve at the carpal tunnel. Adopted from Demircay, et al., 2011.

Pattern of division of main trunk of median nerve and its main branches

Standard anatomy books describe that distal to the carpal tunnel, the median nerve divides into lateral and medial branches. The lateral branch gives off the thenar motor branch which supplies the thenar muscles of the hand: flexor pollicis brevis, abductor pollicis brevis, and opponens pollicis. The lateral branch then subdivides into three proper palmar digital nerves to supply the two sides of the thumb and radial side of the index finger. The branch to the index finger provides a branch to the first lumbrical. The medial branch subdivides into two common palmar digital nerves, lateral and medial. The lateral common nerve gives a branch to the second lumbrical and subdivides to supply the adjacent sides of the index and middle finger. The medial common nerve subdivides to supply the adjacent sides of the middle and ring finger (Standring, 2016)

High division of the median nerve was classified as Lanz group III variation of median nerve at the carpal tunnel (Lanz, 1977). Henry, et al., (2015) reported a prevalence of 2.6%. Raviprasanna, et al., (2014) in their study of 51 cadavers described division proximal to flexor retinaculum in 11.76%, within carpal tunnel in 23.52% and distal to FR in 64.7%. Takami, et al., (2001) described division of median nerve into 2 (ulna and radial) at the level of distal third of the forearm with the ulna division passing through a separate compartment within the transverse carpal ligament.

Pierre Jerome, et al., (2010) in their MRI study of 194 patients reported division proximal to FR in 6.1%, within, 18%, distal 75.9%. They also reported a case of trifid nerve within the carpal tunnel.

A bifid median nerve has been associated with aberrant branches and an increased rate of carpal tunnel syndrome. Bayrak, et al., (2008) in an ultrasound study found a prevalence of 19% in patients with CTS compared to 9% in healthy controls. However other ultrasound studies found no significant difference in prevalence of bifid median nerve between CTS patients and healthy controls (Granata, et al., 2011)

Lanz, (1976) reported that the presence of a bifid nerve was often associated with a persistent median artery. Henry, et al (2015) in their meta-analysis found that Lanz III was associated with PMA in 63% of the hands. Iatrogenic injury to this artery during Carpal Tunnel Release (CTR) may significantly affect circulation in the forearm and hand (Agarwal, et al., 2014).

Jeon, et al., (2002) reported injury to the common digital branch of median nerve due to high bifurcation of the median nerve at the level of the wrist crease.

Lanz, (1976) also described accessory branches of median nerve arising either proximal (Group IV) or distal (Group II) to the flexor retinaculum. Henry, et al.,

(2015) in their meta- analysis found a pooled variance of 5.3% for Group II and 3.1 % for Group IV variations in cadaveric studies and 3.4% and 2 % respectively intraoperatively during carpal tunnel release.

Origin, course and distribution of thenar motor branch of median nerve

The thenar motor branch of the median nerve has been described to arise from the main trunk of median nerve or from its lateral division and breaks into muscular branches which supply the muscles of the thenar eminence: opponens pollicis, abductor pollicis brevis and flexor pollicis brevis.

Most studies describe the origin of thenar motor branch of median nerve from the lateral division of median nerve (Henry, et al., 2015). Olave, et al., (1996) gave special attention to a thenar motor branch given in the distal part of forearm.

Thenar motor branch variations are classified as Lanz Group I variations which are further subdivided into four subdivisions (Table 2)

Table 2: Thenar motor branch variations

Group	Description
IA	Thenar motor branch of the median nerve starts beneath the transverse ligament and then bends around its distal edge (subligamentous).
IB	Thenar motor branch originates from the radial side of the median nerve and then passes through the transverse ligament (transligamentous).
IC	Thenar motor branch arises from the ulnar side of the median nerve.
ID	Thenar motor branch bends around the distal edge of the ligament (supraligamentous)

Many studies have reported data on the origin and course of thenar motor branch of median nerve (Demircay, et al, 2011; Hurwitz, 1996; Lanz, 1977; Olave, et al., 1996; Perreira, et al., 2013;Tountas, et al, 1987).

Henry, et al., (2015) in their Meta-analysis found that the extraligamentous course was most common with a pooled variance of 75%, with subligamentous 13.5% and transligamentous 11.3%. There were geographical differences. The extraligamentous course was 73.5%, 63.7%, 78.7% in the US, Europe and Asia respectively. The subligamentous and transligamentous were more common in European studies. The radial or anterolateral side branching of the TMB from the median nerve was more prevalent accounting for 97.5%.

Lily and Magnell, (1985) reported loss of thenar motor function in two patients seen after surgical release of carpal tunnel syndrome. Both patients were found to have denervation of thenar muscles. In both instances, the take off of the thenar motor branch was quite ulnarward and superficial.

Mackinnon and Dellon, (1988) in their study of the orientation of the motor fascicle of the median nerve in the carpal tunnel in 50 hands found that the thenar motor branch was located on the radial-volar aspect of the median nerve in 60% of the hands, the central-volar aspect in 22%, and between these two locations in the remaining 18%. In 56% of the hands, the thenar motor branch passed through a separate distinct fascial tunnel before entering the thenar muscles. They concluded that awareness of these patterns will facilitate appropriate surgical management of thenar muscle weakness or wasting associated with the carpal tunnel syndrome.

Lanz, (1977) reported variations in the course of the median nerve in12% of 246 hands. The thenar motor nerve was extraligamentous in 46% of cases, subligamentous in 31% of the cases, and transligamentous in 23% of cases.

Hurwitz, (1996) in his study of 80 operations in 61 patients for carpal tunnel syndrome gave special attention to the course of the thenar motor branch and its variations. He found an anomalous origin of the branch in 21%. Multiple thenar motor branches occurred in 12.5%. He drew special attention to an additional anomaly where the thenar motor branch lies superficial to the flexor retinaculum buried in a hypertrophic preligamentous muscle. The nerve can easily be injured during splitting of the flexor retinaculum in this anomaly. He found this variation in 9% of their patients. He recommended that the nerve should be approached from ulnar side to minimize risk to lesion.

Olave, et al., (1996) reported normal anatomy of the thenar motor branch of the median nerve in 48.3% of 60 cases, 18.3% of the cases were in Lanz Group 1A, 15% in Lanz Group 1B, 16.7% of the cases in Lanz Group 1C, an accessory thenar motor branch were found in 23 cases.

Kozin, (1998) dissected 101 fresh frozen cadavers, in 7% of the cases thenar motor branch of the median nerve passed through the flexor retinaculum, in 74% of the cases recurrent nerve passed distal to the FR through separate obliquely oriented fascia and in 19% of the cases it passed distal to the FR but did not pass through the obliquely oriented fascia. He concluded that the transligamentous branch is uncommon and the reported high incidence of branches passing through the FR can be explained by mistakenly combining thenar motor branches passing through the obliquely oriented fascia with the recurrent nerves passing through FR.

The motor nerve is normally described to supply the abductor pollicis brevis, opponens pollicis and superficial head of flexor pollicis brevis. Falconer and spinner, (1985) reported the TMB innervating the 3 muscles in 90% of the cases while the

APB and OP were innervated in 10%. Olave, et al. (1996) described 3 patterns. Type I, 3 muscles innervated in 50%, Type II, ABP and OP in 40%, Type III, independent branches to APB, OP and superficial FPB in 10%.

2.5 Topographical localization of median nerve and its main branches

Little information is available on the topographical localization of median nerve and its motor branch in the palm. Olave, et al., (1996) reported a mean distance of 34.6 mm from the distal wrist crease to the origin of TMB with no significant differences between right and left hands. He also reported that the TMB made an angle of 66.8 ± 7.9 degrees with the longitudinal axis of the hand.

Ozcanli et. al, (2010) in their study of defining a safe zone for carpal tunnel surgery reported that the distance between the distal wrist crease and TMB was 28.1 ± 7.1 mm. They also noted that though there are usually three wrist flexion creases, only the distal crease is of sufficient consistency to be used as a reliable landmark. Olave, et al, (1996) noted the importance of knowing with accuracy the distances in relation to certain points of reference such as the distal wrist crease and the longitudinal axis of the hand, and the angle that this branch forms in making its course, so as to avoid injuries from surgical intervention in this region.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study site

The study was conducted at the Human Anatomy Laboratory; Moi University School of Medicine which is based at the Moi Teaching and Referral Hospital (MTRH) situated in Eldoret, Kenya, about 310 kilometres Northwest of Nairobi the capital city of Kenya. MTRH is situated along Nandi road, in Eldoret, country's fifth largest town, the headquarters of Uasin Gishu County, in the North Rift of Kenya. MTRH is a tertiary health institution with close to 1000 total bed capacity; it is the second largest teaching and referral hospital in the country after Kenyatta National Hospital. It serves as a teaching hospital for Moi University College of Health Sciences. Several other scholars from various educational institutions come to this hospital for attachments. It also serves as a referral health institution with a wide catchment area including Western part of Kenya, Eastern part of Uganda and Southern Sudan with at least 20 million people, almost half the population of Kenya (http://www.mtrh.go.ke/?page_id=598).

3.2 Study design

This was a descriptive anatomical cross sectional study involving the observation of the variations in the course and distribution of the median nerve and its branches in the carpal tunnel in cadaveric specimens at the Department of Human Anatomy, Moi University. The study period was from October 2019 to March 2020.

3.3 Study population

Cadavers of a selected adult black Kenyan population from the Department of Human Anatomy Laboratory were used in this study. The cadavers were sourced from MTRH mortuary and were from a selected region, Western Kenya, which is part of the MTRH catchment area.

3.4 Eligibility Criteria

3.4.1 Inclusion Criterion

Upper limbs from cadavers of adult black Kenyans were included. Only cadavers or limbs with preserved anatomy were used in this study.

3.4.2 Exclusion Criterion

Limbs deformed due to trauma or any medical conditions were excluded.

3.5 Sample size determination

At Moi University Anatomy Laboratory, the average number of cadaveric limbs (either right or left) that can be attained is 60. Therefore, all upper limbs that met the inclusion criteria were included in the study. The majority of the limbs available at the department were disarticulated at the scapulothoracic region therefore determination of sex was impossible in such specimens. However, from available literature, no sexual differences have been observed in the distribution of the median nerve among populations studied (Henry et al., 2015). Left sided upper limbs were chosen with a toss of a coin and studied so as to avoid duplication of data from limbs of both sides of the same cadaver. There were no significant differences in the course and distribution of median nerve and its branches at the carpal tunnel in right or left limbs in the available literature (Henry et al., 2015).

A total of 56 individual left side upper extremities were studied.

3.6 Materials and methods

Cadavers were dissected according to the techniques described by The Cunningham's Manual of Practical Anatomy 16th Edition (Koshi, 2017).

The following incisions were made in the palmer region:

- From the middle of a transverse incision at the palmar crease of the wrist, an incision was made along the medial border of the thenar eminence to the tip of the thumb.
- A longitudinal incision was made from the middle of the transverse incision at the proximal crease of the wrist to the tip of the middle finger.
- Transverse incision at the root of the fingers.
- Longitudinal incision along the index, middle and ring fingers.

Skin flaps were reflected; the palmar aponeurosis was exposed and divided at the distal border of flexor retinaculum and reflected distally. The superficial palmar arch was removed. The flexor retinaculum was divided at the midline, avoiding damage to underlying structures, thenar muscles and lumbricals were identified. The main trunk of median nerve and its muscular branches in the hand were traced, studied and any variations described.

The course and distribution of the median nerve with its branches in the carpal tunnel was described and photographs taken. The distal wrist crease and the longitudinal axis of the hand were taken as the reference points (Olave, et al., 1996). Measurements were taken using digital Vernier calipers accurate to 0.01mm. The distance between the distal wrist crease and origin of TMB was measured. The distance between the longitudinal axis of the hand and the termination of TMB into its muscular branches was also measured (Figure 7). Data was collected using structured data collection sheet.

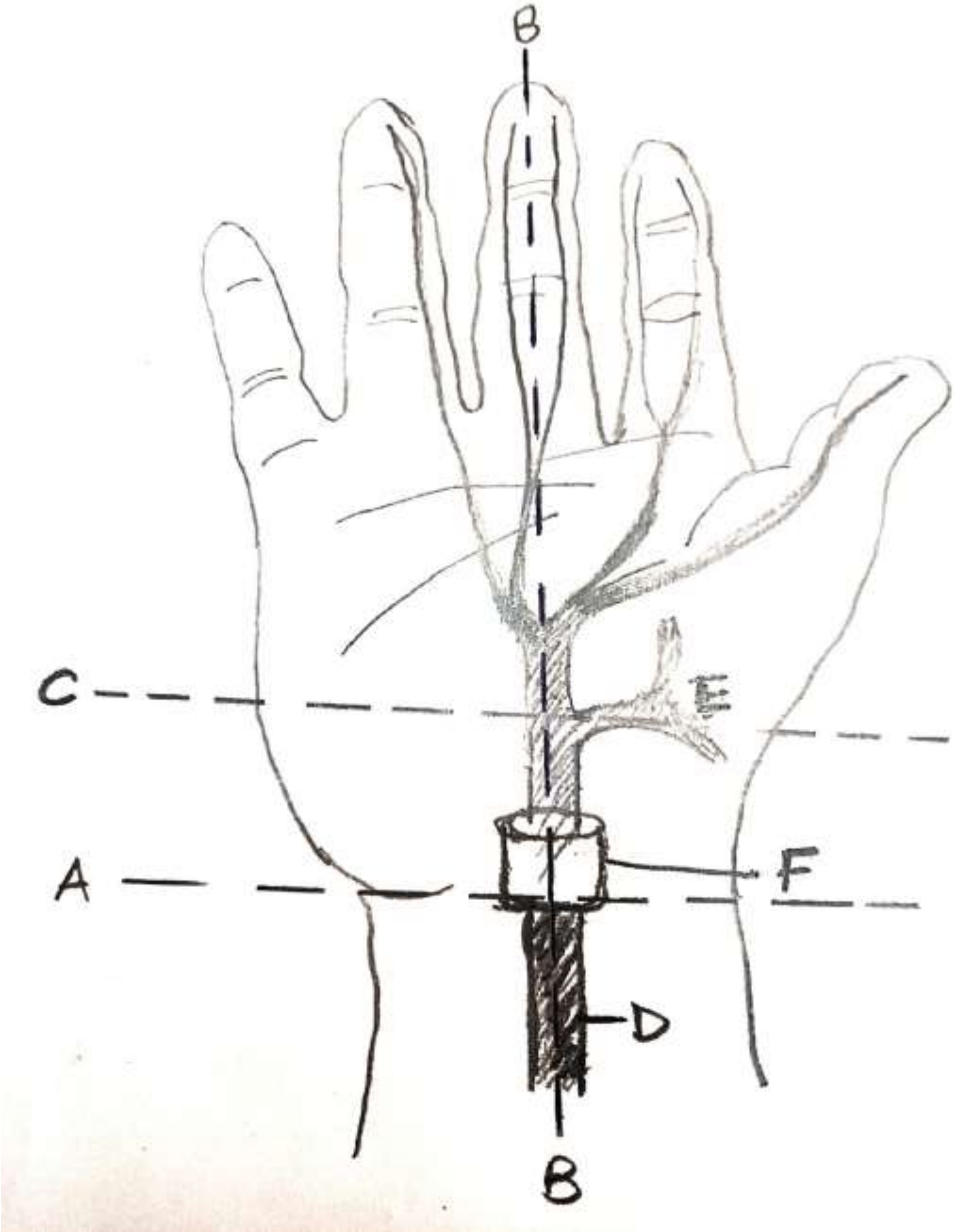

Figure 7: Measurements of the topographical localization of median nerve.

A- Distal wrist crease, B- Longitudinal axis of the hand, C- Point of origin of thenar motor branch, D- Median nerve, E- Thenar motor branch, F- Carpal tunnel. Adopted from Olave, et al., 1996.

3.7 Data analysis, management and presentation

Data analysis was conducted with the aid of STATA version 13 SE. Categorical variables such as the course and distribution of median nerve were summarized as frequencies and corresponding percentages. Continuous variables such as the distance of the TMB from the distal wrist crease were summarized as mean and the corresponding standard deviation if they assumed the Gaussian distribution. If Gaussian assumptions were violated then the median and the corresponding inter quartile range were used to summarize these characteristics. Gaussian assumptions were assessed using Shapiro-Wilk test for normality.

Data captured using structured data collection forms was entered into an electronic database. The database was encrypted with a password to ensure confidentiality. The password was only accessible to the main investigator. The forms, once conversion to electronic database was complete, were shredded upon completion of the study and disposed of in an appropriate way.

The data obtained above was recorded and coded in structured data collection sheets. Computer hardware, memory sticks and compact disks were used to store the data obtained for future backup. Photographs of dissected specimens were recorded using a digital camera. Finally the data obtained was presented in form of tables and figures.

3.8 Ethical considerations

Ethical approval was sought from the Institution Research and Ethics Committee (IREC) Moi University and the Department of Human Anatomy prior to commencement of the study. The study approval number was FAN: 0003450.

The study was conducted in accordance with the Anatomy Act Chapter 243-9 (REVISED EDITION OF 2012) of the Laws of Kenya which entitles a person registered as a student in an approved school of anatomy to examine and conduct anatomical research on human cadavers as long as the requirements stipulated in the act are strictly adhered to. Data confidentiality was strictly maintained and this included use of passwords in the database.

Results obtained will be disseminated through an oral defense of thesis and thereafter the results may be presented at relevant conferences/seminars and publication in a peer reviewed scientific journal.

3.9 Scope and limitations

1. Specimens used in this study included formalin prefixed scapulothoracic disarticulated upper extremities hence determination of gender was not be possible in the already prepared limbs.
2. The exact anatomical position of the median nerve could have been altered during dissection and fixation. This was minimized by mapping the course of the nerve on the external surface of the limbs by the use of hypodermic needles before measurements are taken.

CHAPTER FOUR: RESULTS

4.0 Introduction

The results are based on 56 adult formalin prefixed cadaveric upper limbs from the Department of Human Anatomy, Moi University School of Medicine. There were no missing data in all the cases. All the cadaveric upper limbs were left sided.

4.1 The course of the main trunk of median nerve at the carpal tunnel

In all the cadavers, the median nerve passed deep to flexor retinaculum to enter the palm of the hand.

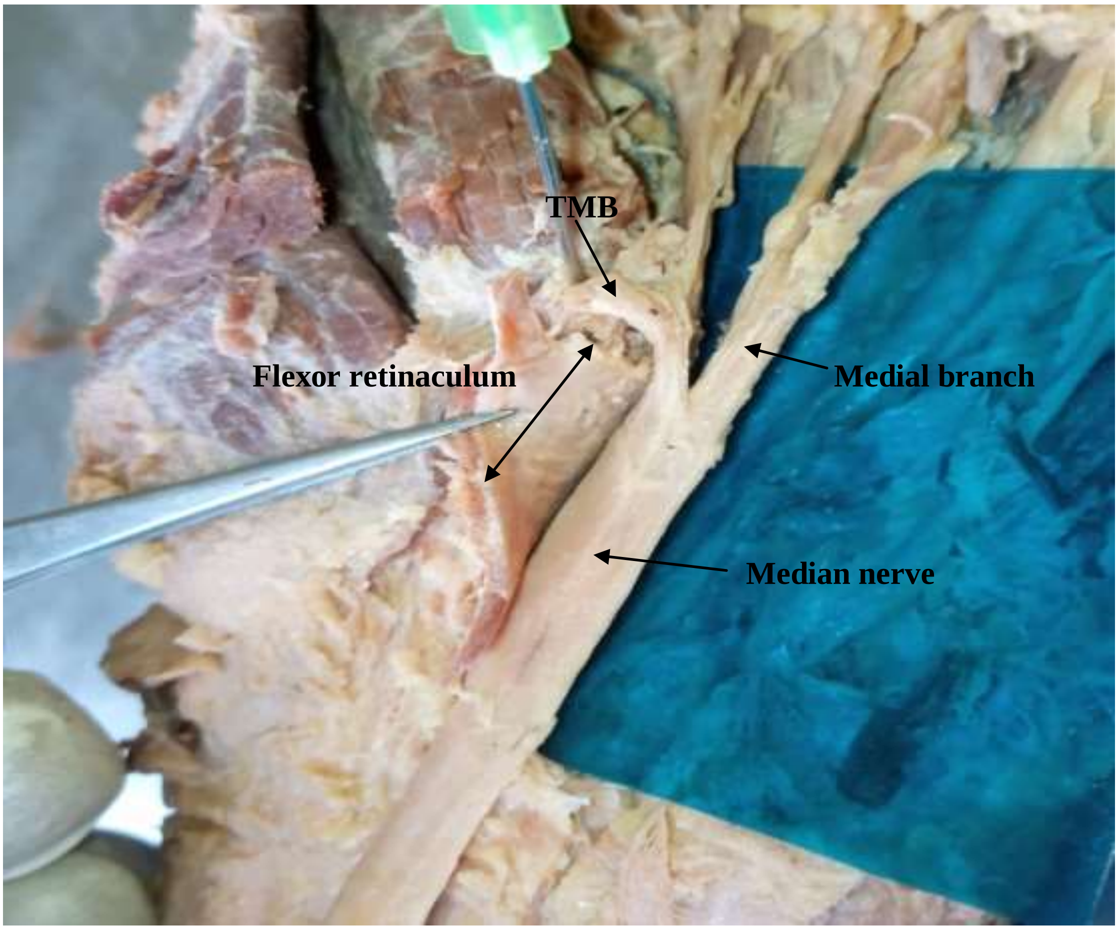

Figure 8: The course of the median nerve deep to the flexor retinaculum.

Table 3: The course of the median nerve at carpal tunnel in relation to longitudinal axis of hand

Position of median nerve		Frequency	Percentage
Does not curve	Radial side	38	67.86
	Middle	12	21.43
	Ulna side	0	0.00
Curves	Radial-ward	2	3.57
	Ulna-ward	4	7.14
Total		56	100

The position and course of the median nerve within the carpal tunnel showed some variations in relation to the longitudinal axis of the hand. The nerve passed deep to the flexor retinaculum to the palm without curving in 89.29% of the cases. When it did not curve, the median nerve was shifted to the radial side of the carpal tunnel in 67.86%, below the middle of the flexor retinaculum in 21.43%. Median nerve curved within the carpal tunnel diverging to the radial in 3.57% of the cases and to the ulnar side in 7.14% of the cases.

4.2 The pattern of division of the main trunk of the median nerve and its main branches.

In all the cadavers the median nerve divided into 2 main branches, the lateral and medial.

Table 4: Level of division of the main trunk of the median nerve in relation to flexor retinaculum

Level of division	Frequency	Percentage
Distal	43	76.79
Lower 1/3	4	7.14
Middle 1/3	4	7.14
Upper 1/3	0	0.00
Proximal	5	8.93
Total	56	100

Out of the 56 cadaveric specimens, 43 (76.79%) divided into medial and lateral branches distal to the flexor retinaculum, 8 (14.28%) within the flexor retinaculum and 5 (8.93%) proximal to the flexor retinaculum.

Persistent median artery accompanying the median nerve was observed in 2 specimens (3.57%) and in both instances the median nerve divided proximal to the flexor retinaculum.

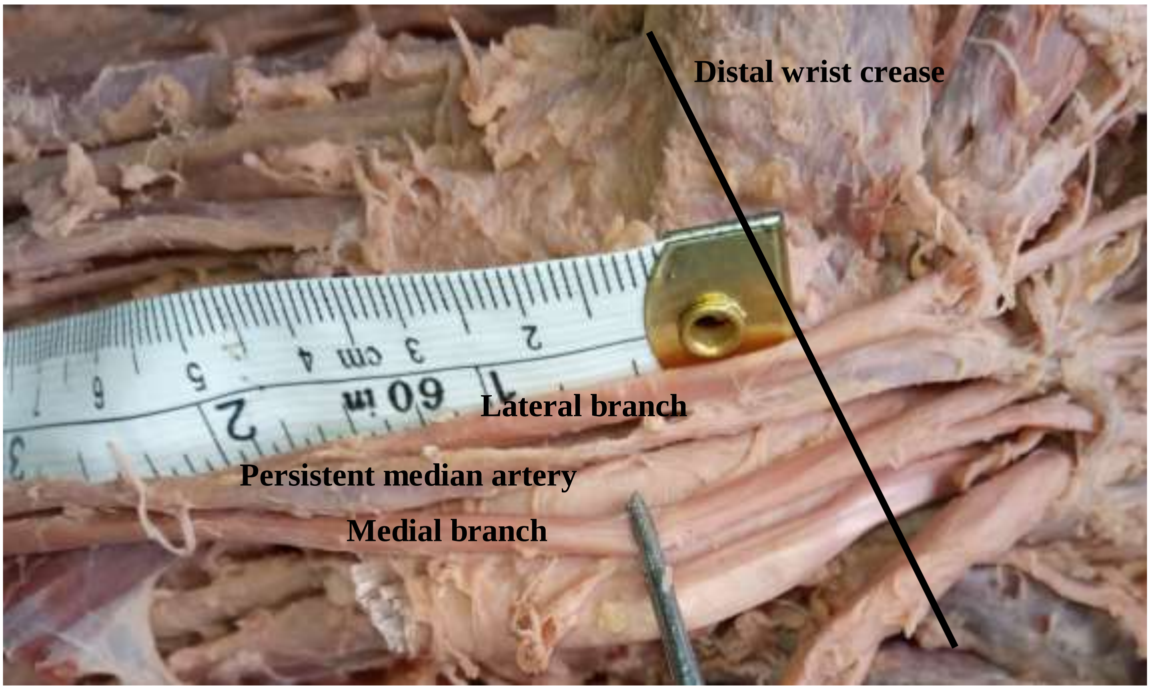

Figure 9: The high division of median nerve proximal to flexor retinaculum

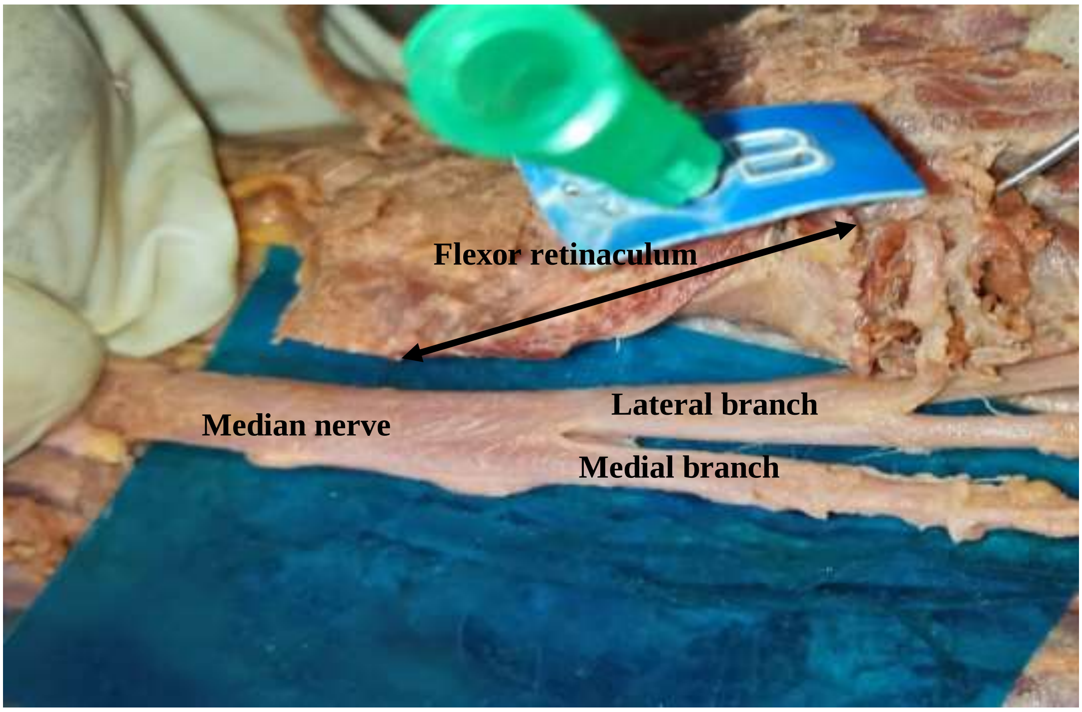

Figure 10: The division of median nerve within the flexor retinaculum.

The lateral branch divided into 3 palmar digital branches while the medial branch divided into 2 common palmar digital branches, in all the cadaveric samples.

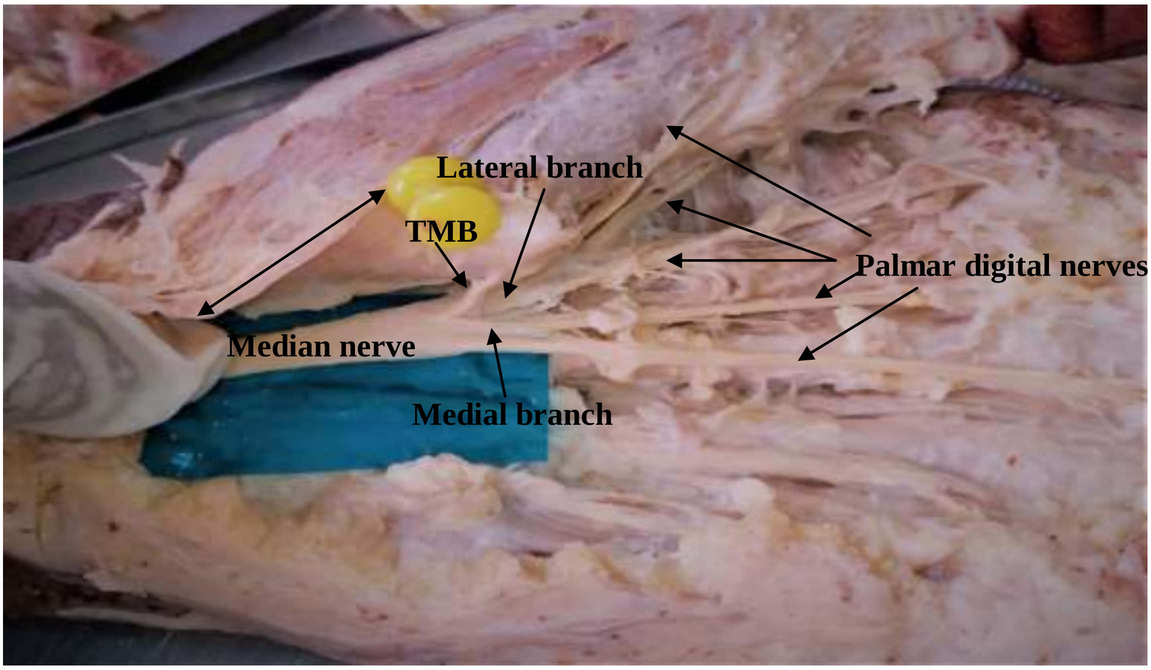

Figure 11: The branching pattern of median nerve at carpal tunnel.

4.3 The origin, course, and distribution of the thenar motor branch of median nerve at the carpal tunnel.

Table 5: Origin the thenar motor branch of median nerve at the carpal tunnel

Origin	Frequency	Percentage
Lateral branch	43	76.79
Main trunk of median nerve	12	21.43
Medial branch	1	1.79
Total	56	100

The thenar motor branch originated from lateral branch in 43 (76.79%) of the specimens, main trunk of median nerve in 12 (21.43%), and medial branch in only 1 (1.79) of the specimens.

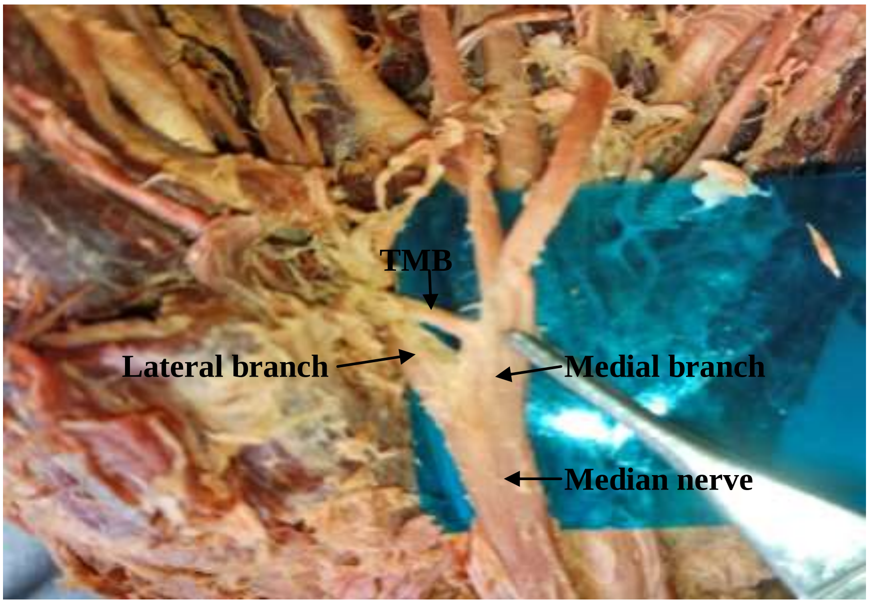

Figure 12: The origin of thenar motor branch from medial branch of median nerve

Table 6: Level of origin of thenar motor branch in relation to flexor retinaculum

Level of origin	Frequency	Percentage
Distal	43	76.79
Lower 1/3	11	19.64
Middle 1/3	2	3.57
Upper 1/3	0	0.00
Proximal	0	0.00
Total	56	100

The TMB arose distal to the flexor retinaculum in 43 (76.79%) of the specimens, 11 (19.64%) in the lower 1/3 of flexor retinaculum and 2 (3.57%) in the middle 1/3 of the flexor retinaculum.

Table 7: Side of origin of thenar motor branch

Side of origin	Frequency	Percentage
Lateral	44	78.57
Intermediate	11	19.64
Medial	1	1.79
Total	56	100

The thenar motor branch of median nerve branched from the lateral side of median nerve in 44 (78.57%) of the cadavers, 11 (19.64%) from the intermediate or ventral aspect and only 1 (1.79%) from the medial aspect of the nerve.

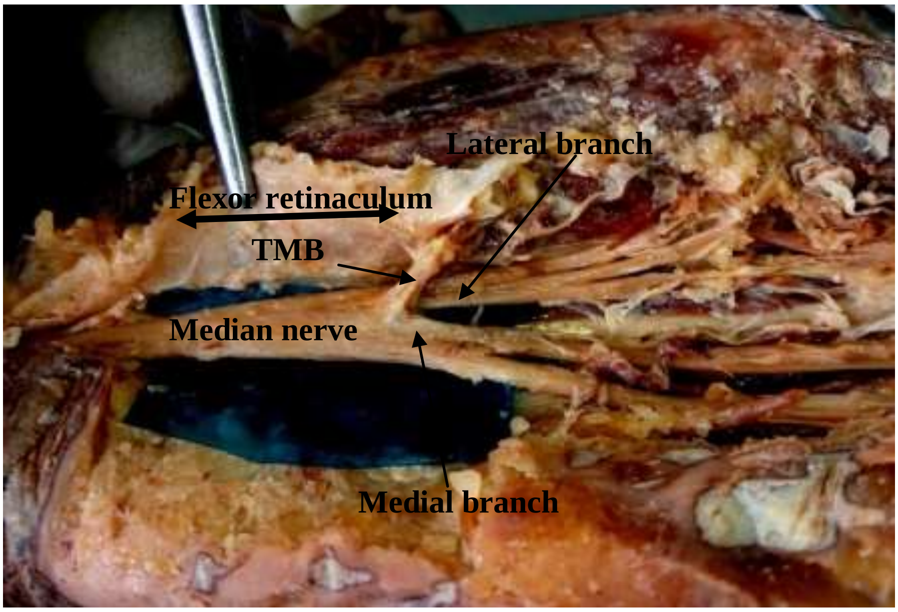

Figure 13: The origin of TMB from intermediate aspect of median nerve

Table 8: The course of thenar motor branch

Course of thenar motor branch	Frequency	Percentage
Extraligamentous	43	76.79
Subligamentous	13	23,21
Transligamentous	0	0.00
Supraligamentous	0	0.00
Total	56	100

Course of TMB was extraligamentous in 43 (76.79%) and subligamentous in 13 (23.21%) of the cadaveric specimens.

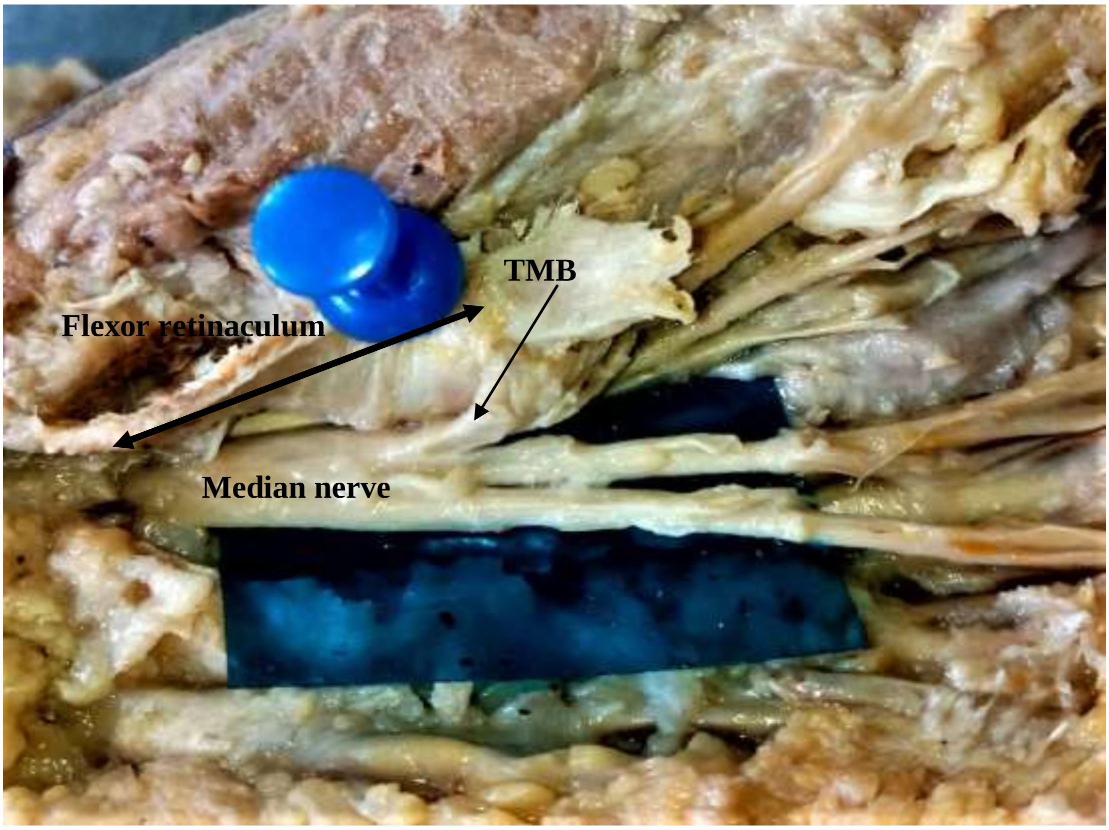

Figure 14: The subligamentous course of thenar motor branch of median nerve

Table 9: The distribution of thenar motor branch

Distribution	Frequency	Percentage
All thenar muscles (APB,OP,FPB)	46	82.14
OP,APB	10	17.86
Total	56	100

The thenar motor branch supplied all the three thenar muscles (abductor pollicis brevis, opponens pollicis and flexor pollicis brevis) in 46 (82.14%) and only the opponens pollicis and abductor pollicis brevis in 10 (17.86%) of the cadaveric specimens.

Table 10: Presence of accessory thenar motor branches

Accessory thenar branches	Frequency	Percentage
Present	7	12.50
Absent	49	87.5
Total	56	100

Accessory thenar branches were present in 7 (12.50%) of the specimens and in all the cases they originated from the median nerve distal to the flexor retinaculum.

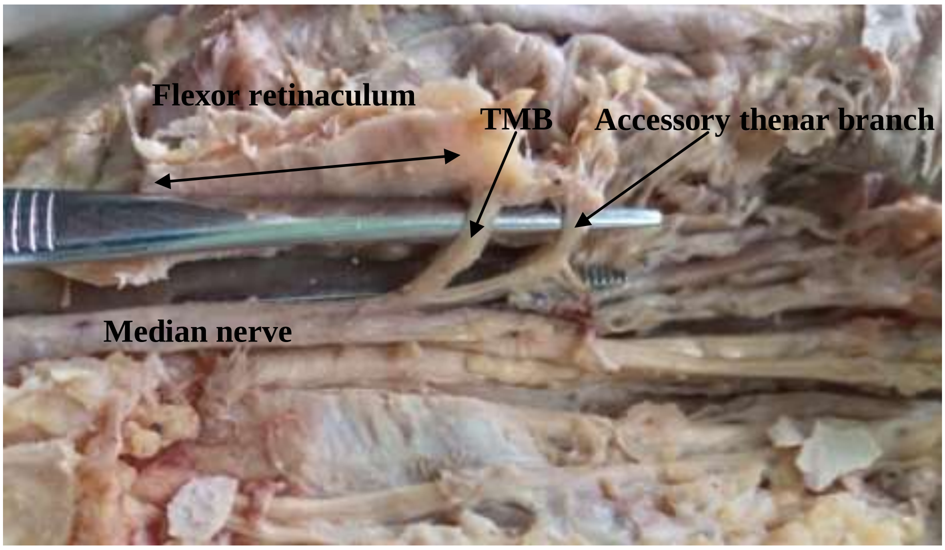

Figure 15: The accessory thenar motor branch of median nerve given distal to flexor retinaculum

Table 11: Median nerve variations at the carpal tunnel according to Lanz classification

Lanz Group	Frequency	Percentage
0	36	64.29
IA	11	19.64
IB	0	0.00
IC	1	1.79
ID	0	0.00
II	7	12.50
IIIA	3	5.36
IIIB	2	3.57
IIIC	0	0.00
IVA	0	0.00
IVB	0	0.00

Out of the 56 specimens, 36 (64.29%) were in Lanz Group 0, 11 (19.64%) in Group IA, 1 (1.79%) in Group IC, 7 (12.50%) in Group II, 3 (5.36%) in Group IIIA, and 2 (3.57%) in Group IIIB.

4.4 The topographical localization of median nerve and its main branches

Table 12: Location of main trunk of medial nerve in relation to longitudinal axis of hand

Location	Frequency	Percentage
Radial side	44	78.57
Middle	12	21.43
Ulnar side	0	0.00
Total	56	100

The main trunk of median nerve was located on the radial side of the longitudinal axis of the hand in 44 (78.57%) of the cadavers and in the middle in 12 (21.43%) of the specimens.

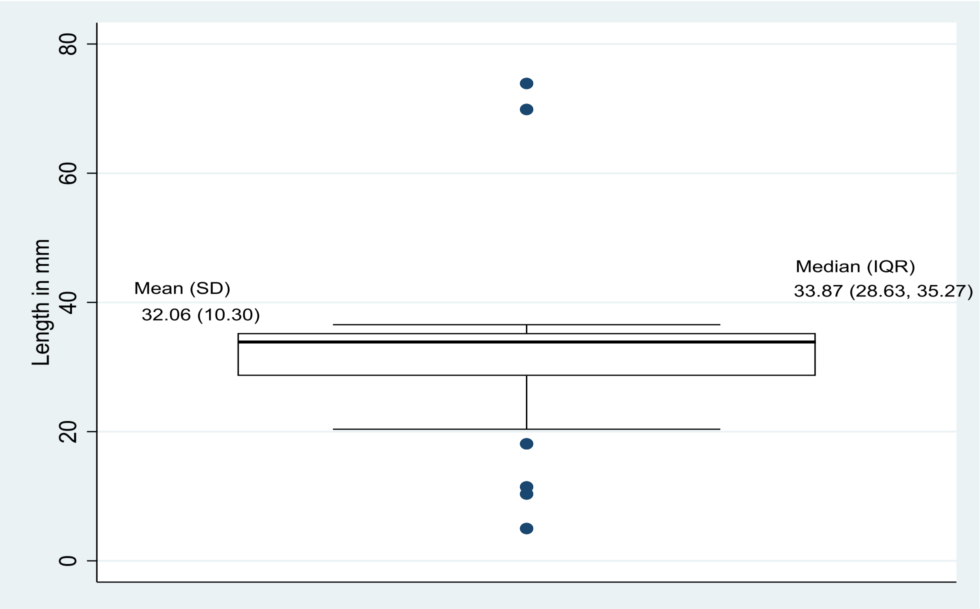

Figure 16: The point of division of main trunk of median nerve into medial and lateral divisions in relation to distal wrist crease

The point of division of the median nerve into medial and lateral branches was located 32.06 +/- 10.30 mm from the distal wrist crease.

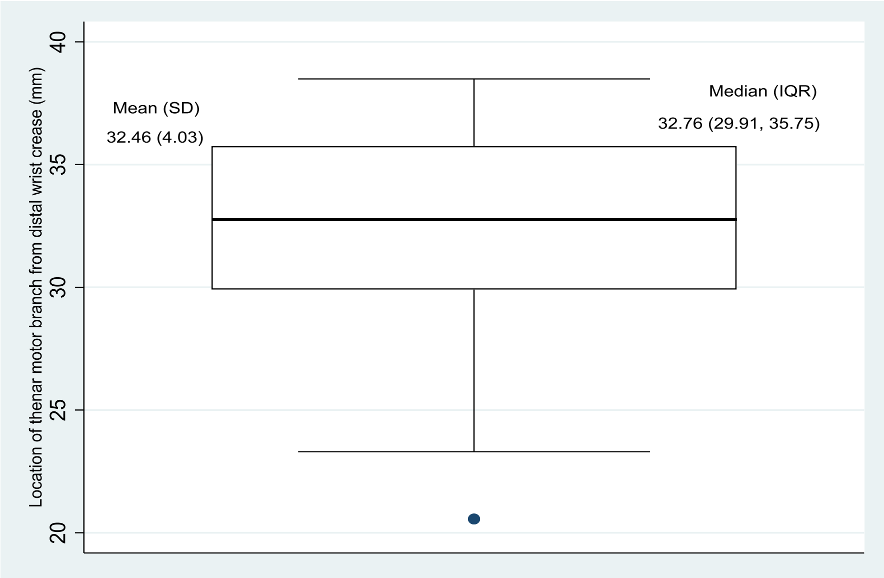

Figure 17: The location of thenar motor branch from distal wrist crease

The thenar motor branch was located 32.46 +/- 4.03 mm from the distal wrist crease

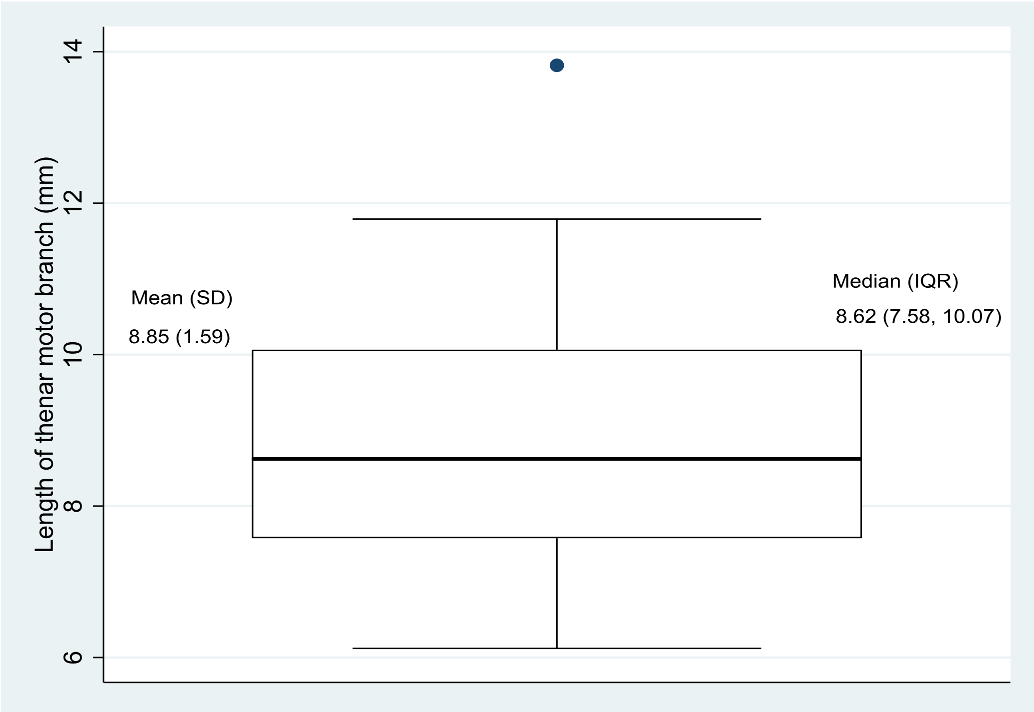

Figure 18: The distance from longitudinal axis of hand to point of division of thenar motor branch into its smaller muscular branches

The distance from the longitudinal axis of the hand to the point of division of the thenar motor branch into its small muscular branches was 8.85 +/- 1.59 mm.

CHAPTER FIVE

5.0 DISCUSSION

5.1 The course of main trunk of median nerve at the carpal tunnel

In the present study the main trunk of the median nerve passed deep to the flexor retinaculum in all the cadaveric specimens. This concurs with the description by Standring, 2016. Singer, et al., (2001) also observed that the nerve passes dorsal to the flexor retinaculum to enter the palm.

In this study, the position and course of the median nerve within the carpal tunnel showed some variations in relation to the longitudinal axis of the hand. The nerve passed deep to the flexor retinaculum to the palm without curving in most (89.29%) of the cases. When it did not curve, the median nerve was shifted to the radial side or at the middle of the carpal tunnel. This is in agreement with Schmidt, (2007) who found that 2/3 of the time the median nerve passes deep to flexor retinaculum without curving and when it did not curve it was mostly found on the radial side the carpal tunnel. It also concurs with Sanmugalingam, et al., 2020 who observed a radial sided dominance of median nerve course.

The position of the median nerve at the carpal tunnel is surgically relevant during carpal tunnel surgery which involves splitting of transverse carpal ligament, as there has been debate about the optimal approach of the incision. The findings of this study suggest a radial sided dominance of median nerve position and therefore a 3rd web space axis approach like the one suggested by Boughton, et al., 2010 or radial border of ring finger (Samarakoon, et al., 2014) may provide better and safer access to the median than the ulnar ring finger approach (Hong, et al., 2006 and Wheatley, 1996) as it reduces risk of injury to ulna artery. Corticosteroid injections for treatment of carpal tunnel syndrome can also be done in the same region.

5.2 The pattern of division of the main trunk of the median nerve and its main branches (medial and lateral).

In the present study the median nerve divided into 2 main branches, the lateral and medial, in all the cadaveric specimens. This concurs with the descriptions by Standring, (2016). In 76.79% of specimens the median nerve divided distal to the flexor retinaculum, while 14.28% within the flexor retinaculum and 8.93% proximal to the flexor retinaculum. This study is in agreement with an MRI study of Pierre Jerome, et al., 2010 who reported division proximal to FR in 6.1%, within, 18%, distal 75.9%. However it contrasts with the study of Raviprasanna, et al., (2014) who found 64.7% distal to FR, 23.52% within and 11.76 proximal to flexor retinaculum. This difference could be due to the low sample sizes in our study and that of Raviprassana et al., (2014) or the geographical and racial difference in the branching pattern of the median nerve at the carpal tunnel.

Persistent median artery was found in 3.57% of the specimens and in all cases it was associated with a high division of median nerve. This agrees with most studies who found a low occurrence (Henry et al., 2015 and Raviprasanna, et al., 2014). However, it contrasts with a study by Cheruiyot, et al., (2017) who found a prevalence of 19.35%. This difference can be attributed to the fact that Cheruiyot, et al., (2017) study was a dissection by undergraduate students who may not have had clear objectives to study and also that their sample size was higher.

Takami, et al., (2001) described division of median nerve into 2 (ulna and radial) at the level of distal third of the forearm with the ulna division passing through a separate compartment within the transverse carpal ligament. A bifid median nerve has been associated with atypical branches and an increased rate of carpal tunnel syndrome. Bayrak, et al., (2008) in an ultrasound study found a prevalence of 19% in patients with Carpal Tunnel Syndrome compared to 9% in healthy controls. However other ultrasound studies found no significant difference in prevalence of bifid median nerve between Carpal Tunnel Syndrome patients and healthy controls (Granata, et al., 2011).

Lanz reported that the presence of a bifid nerve was often associated with a persistent median artery. Henry, et al., (2015) in their meta-analysis found that Lanz III was associated with PMA in 63% of the hands. In this study Lanz Group III was associated with PMA in 40%. Iatrogenic injury to this artery during Carpal Tunnel Release may significantly affect circulation in the forearm and hand (Agarwal, et al., 2014).

5.3 The origin, course, and distribution of the thenar motor branch of median nerve at the carpal tunnel.

The thenar motor branch originated from lateral branch in 76.79% of the specimens, main trunk of median nerve in 21.43%, and medial branch in only 1.79 % of the specimens. This agrees with most referenced authors that the TMB is derived from the lateral division of median nerve in most cases (Henry, et al., 2015).

The thenar motor branch of median nerve branched from the lateral side of median nerve in 78.57% of the cadavers, 19.64% from the intermediate or ventral aspect and only 1.79% from the medial aspect of the nerve. This concurs with Henry, et al., (2015) who found that the radial or anterolateral side branching of the TMB from the median nerve was more prevalent accounting for 97.5%. This is also in agreement with Mackinnon and Dellon, (1988)who found that the motor branch was located on the radial-volar aspect of the median nerve in 60% of the hands, the central-volar aspect in 22%, and between these two locations in the remaining 18%. This study found a case of median nerve from medial side of median nerve. This is of great surgical importance in carpal tunnel surgery as it is at high risk of iatrogenic injury even with ulna sided incisions of transverse carpal ligament.

Course of TMB was extraligamentous in 76.79% and subligamentous in 23.21% of the cadaveric specimens. This agrees with most studies. Henry, et al., (2015) in their Meta analysis found that the extraligamentous course was most common with a pooled variance of 75%, with subligamentous, 13.5% and transligamentous, 11.3%. They reported geographical differences. The subligamentous type was higher in Europeans (24.6%) than Asians (12.6%) and Americans (7.1%). The European value nears the one of this study. The transligamentous type was higher in Americans (19.4%) than Europeans (11.7%) and Asians (8.7%). This study did not find any transligamentous variant of TMB. The prevalence of the transligamentous TMB is highly variable with some studies reporting 0% (Olave, et al., 1996; Pereira, et al., 2013; Raviprasanna, et al., 2014) while others report upto 80% (Johnson & Shrewsbury, 1970). Kozin, et al., (1998) concluded that the transligamentous branch is uncommon and the reported high incidence of branches passing through the flexor retinaculum can be explained by mistakenly combining TMB passing through the obliquely oriented fascia with the TMB passing through flexor retinaculum. He explained that these oblique fibres should not be considered as part of flexor retinaculum. However the highly variable nature of the TMB may account for these differences.

The thenar motor branch supplied all the three thenar muscles (Abductor pollicis brevis, Opponens pollicis and Flexor pollicis brevis) in 82.14% and only the opponens pollicis and abductor pollicis brevis in 17.86% of the cadaveric specimens. This concurs with Falconer and Spinner, (1985) who reported the TMB innervating the 3 muscles in 90% of the cases while the APB and OP were innervated in 10%. Olave et al., (1996) described 3 patterns. Type I three muscles innervated in 50%, type II ABP and OP in 40%, type III independent branches to APB, OP and superficial FPB in 10%. This distribution shows that the TMB supplies the important muscles of the thumb which would lead to devastating loss of thumb function. This could also lead to litigations with high legal costs to the surgeon (Krishnan, et al., 2013).

Accessory thenar branches were present in 12.50% of the specimens and in all the cases they originated from the median nerve distal to the flexor retinaculum. This concurs with Ahn, et al., 2010 and Lanz, (1977) who reported 10.2% and 7.2% respectively. It contrasts Alizadeh, et al., 2006; Olave, et al., 1996; Raviprasanna, et al., 2014 who reported 31.7%, 38.3% and 50.97% respectively. Presence of accessory branches is of surgical importance as they may be a source of innervations in case of inadvertent transection of TMB.

5.4 The topographical localization of median nerve and its main branches at the carpal tunnel in adult black Kenyan population.

There is paucity of information regarding the topographical localization of median nerve at the carpal tunnel. The thenar motor branch was located 32.46 ± 4.03 mm from the distal wrist crease. This is in agreement with a study by Olave, et al. (1996) who reported a mean distance of 34.6 ± 3.9 mm from the distal wrist crease to the origin of TMB with no significant differences between right and left hand. It also concurs with Ozcanli, et. al, (2010) who reported that the distance between Distal Wrist Crease and the TMB was 28.1 ± 7.1 mm.

The distance from the longitudinal axis of the hand to the point of division of the thenar motor branch into its small muscular branches was 8.85 ± 1.59 mm. This concurs with Olave, et al., (1996) who found7.0 ± 2.9mm.

From this study in can be deduced that the area 28mm to around 37mm distal to Distal Wrist Crease and around 10mm radial to the longitudinal axis is a high risk area which should be avoided when making incisions in the palm as this can lead to iatrogenic injury to the median nerve and especially its thenar motor branch.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The course and distribution of the median nerve and its branches at the carpal tunnel was variable.

The main trunk of median nerve passed deep to the flexor retinaculum to enter the palm in all the cases. The nerve coursed in the radial side of the carpal tunnel in all the cases.

The median nerve divided distal to the flexor retinaculum to medial and lateral branches in most cases. Sometimes the median nerve divided proximal to the flexor retinaculum and was associated with persistent median artery.

The thenar motor branch originated from lateral branch in most cases. The course of the thenar motor branch was extraligamentous in most of the cases and supplied the three thenar muscles.

The median nerve and its motor branch were located to the lateral side of the longitudinal axis of the hand in all the cases. The thenar motor branch was located 32.46 ± 4.03mm from the distal wrist crease and its point of termination 8.85 ± 1.59mm to the radial side of the longitudinal axis of the hand.

6.2 RECOMMENDATIONS

1. Surgeons should be aware of the anatomic variations of the median nerve and its branches at the carpal tunnel and put them into account during wrist and hand surgeries.
2. Ulnar sided approach to the carpal tunnel reinforced to prevent inadvertent damage to the median nerve and its branches which are located radial to the longitudinal axis of the hand.
3. The area 28mm to around 37mm distal to DWC and around 10mm radial to the longitudinal axis is a high risk area which should be avoided when making incisions in the palm as this can lead to iatrogenic injury to the motor branch of median nerve.
4. Use of recent technological advances like MRI and ultrasound to identify median nerve variations at the carpal tunnel
5. More studies on the influence of sex and age on the surgical anatomy of median nerve at carpal tunnel.

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APPENDICES

Appendix 1: Equipment and Instruments

1. Measuring instruments: Digital Vernier calipers, tape measure.
2. Dissecting instruments: scalpel, blade holders, forceps, retractors
3. Digital camera
4. Stationery
5. Gloves
6. Printer
7. Hypodermic needles
8. Sutures (Nylon 2-0)

Appendix 2: Data Collection Tool

DATE …………………………………………..

IDENTIFICATION CODE …………………………………

SIDE OF LIMB RIGHT……………….

LEFT………………………..

1. COURSE OF MEDIAN NERVE

1. Deep to flexor retinaculum…………………………….
2. Superficial to flexor retinaculum………………………

2. POSITION OF MEDIAN NERVE IN CARPAL TUNNEL IN RELATION TO LONGITUDINAL AXIS OF HAND

1. Does not curve
   a. Ulnar side…………………………
   b. Middle……………………………
   c. Radial side………………………...
2. Curves
   a. Ulnarwards……………………….
   b. Radialwards………………………

3. LEVEL OF DIVISION OF MEDIAN NERVE IN RELATION TO FLEXOR RETINACULUM

1. Proximal…………………………..
2. Upper 1/3………………………….
3. Middle 1/3………………………..
4. Lower 1/3………………………….
5. Distal………………………………

4. NUMBER OF DIVISIONS 1…..... 2…..… 3…….

OTHER……

5. PRESENCE OF PERSISTENT MEDIAN ARTERY

1. Present……………
2. Absent……………

6. PRESENCE OF ACCESSORY LUMBRIAL MUSCLE

1. Present…………..
2. Absent…………..

7. ORIGIN THENAR MOTOR BRANCH

1. Main trunk of median nerve……………………..
2. Lateral branch……………………………………
3. Medial branch……………………………………
4. Others (specify)…………………………………

8. LEVEL OF ORIGIN OF THE THENAR MOTOR BRANCH IN RELATION TO FLEXOR RETINACULUM

1. Proximal…………………
2. Upper 1/3………………..
3. Middle 1/3………………
4. Lower 1/3……………….
5. Distal……………………

9. SIDE OF ORIGIN OF THENAR BRANCH

1. Lateral
2. Intermediate
3. Medial

10. LENGTH OF THENAR BRANCH ………………MM

11. COURSE OF THENAR MOTOR BRANCH

1. Extraligamentous……………………….
2. Subligamentous…………………………
3. Transligamentous……………………….
4. Supraligamentous………………………

12. DISTRIBUTION OF THENAR MOTOR BRANCH

Muscles innervated (describe)……………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

13. LOCATION OF THE ORIGIN OF THENAR MOTOR BRANCH IN THE PALM IN RELATION TO THE DISTAL WRIST CREASE IN MILLIMETRES…………………….MM

14. ACCESSORY THENAR BRANCHES OF THENAR BRANCH ………………

1. Proximal to flexor retinaculum…………………..
    a. Direct to thenar muscle……………
    b. Joining another branch……………
2. Distal to flexor retinaculum……………………..

15. TERMINAL BRANCHES OF MEDIAN NERVE

a. Point of division in relation to distal wrist crease………..MM

b. Branches(describe)……………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

16. GROUP ACCORDING TO LANZ CLASSIFICATION

1. GROUP 0
2. GROUP I
    a. 1A
    b. 1B
    c. 1C
    d. 1D
3. GROUP II
4. GROUP III
    a. IIIA
    b. IIIB
    c. IIIC
5. GROUP 1V
    a. IVA
    b. IVB

Appendix 3: Time Schedule

Activity	Duration	Date	Participant(s)
Thesis proposal topic selection and development	1 month	January to February 2018	Researcher and supervisors
Presentation of concept paper to the department	2 month	February to April 2018	Researcher and supervisors
Proposal writing	6 months	April 2018 to June 2019	Researcher and supervisors
Submission and approval of proposal by I.R.E.C		September 2019	Researcher and supervisors
Data collection, coding and cleaning	6 months	October 2019 to March 2020	Researcher and supervisors
Thesis write up (results and discussions)	5 months	April 2020 to August 2020	Researcher and supervisors
Submission of thesis for examination after mock defense	1 month	September 2020	Researcher and supervisors
Oral defense of thesis	1 month	January 2021	Researcher and supervisors
Edit of Thesis	1month	February 2021	Researcher and supervisors
Submission of Thesis bound copies	1 month	March 2021	Researcher

Appendix 4: Budget

ITEM	AMOUNT (KSH)
DIGITAL CAMERA	15000
PRINTING AND BINDING	10000
VERNIER CALLIPERS	9000
DATA HANDLING	8000
FLASH DISK	5000
4 RIMS OF PLAIN PAPERS	2000
FOLDERS	1000
IREC FEE	2000
TAPE MEASURE	300
BIOSTATITICIAN	30000
STAPLER& STAPLES	900
PAPER PUNCH	500
TOTAL	86300

Appendix 5:IREC Approval

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
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Tel: 33471/2/3

Reference: IREC/2019/122
Approval Number: 0003450

26th September, 2019

Dr. Langat Patrick Nyigei,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
26 SEP 2019
APPROVED
P.O. Box 4606-30100 ELDORET

Dear Dr. Langat,

SURGICAL ANATOMY OF MEDIAN NERVEAT THE CARPAL TUNNEL IN ADULT BLACK KENYAN POPULATION: A CADAVERIC STUDY

This is to inform you that ***MU/MTRH-IREC*** has reviewed and approved your above research proposal. Your application approval number is ***FAN:0003450.*** The approval period is **26th September, *2019 – 25th September, 2020.***

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***MU/MTRH-IREC***.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***MU/MTRH-IREC*** within 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***MU/MTRH-IREC*** within 72 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. 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.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***MU/MTRH-IREC.***

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Sincerely,

PROF. E. WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD