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Diagnostic accuracy of pre-operative clinical examination in Zone V flexor injuries



Dr. Emmanuel Dwomoh Osei

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Medicine

Johannesburg, 2020

Declaration

I, Dr Emmanuel Dwomoh Osei declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Orthopaedic Surgery at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



(Signature of candidate)

10th day of March 2020 in Johannesburg

DEDICATION

This study is dedicated to Prof. M. T. Ramokgopa, a teacher, a mentor and a father who gave me the great opportunity of studying orthopaedic surgery at the University of Witwatersrand and his support and encouragement throughout these years.

Secondly, this study is also dedicated to my wife and best friend, Dr. Mrs. Christiana Osei-Dwomoh for her tremendous support throughout these years and my children; Obrempong, Nhyira and Odombarimah.

ACKNOWLEDGEMENT

I want to express my heartfelt gratitude to my supervisors: Dr. M. C. Sathekga and Dr. T. I. Sefeane for their supervisory role in making this research a reality.

My sincere gratitude to Dr. Maxwell Jingo and Dr. Brenda Milner for their assistance throughout the research period.

I thank the CEO of Chris Hani Baragwanath Academic Hospital (CHBAH) for granting me the permission to carry out this prospective study.

I also want to thank all the registrars in the orthopaedic surgery department at the University of Witwatersrand who assisted in this research in diverse ways.

Presentations arising from research project

The study was presented at the Combined 65th South African Orthopaedic Association Congress 2019.

ABSTRACT

Background: Zone V flexor injuries can be devastating with significant morbidity. The pre-operative clinical examination not only assists surgeons with preparation but also with efficiency of limited theatre utilisation. Our study aimed at analysing the demographic data of patients who presented to the casualty unit at Chris Hani Baragwanath Academic Hospital (CHBAH) with zone V flexor injuries and also to assess the diagnostic accuracy of pre-operative clinical examination of orthopaedic registrars in these injuries.

Methods: This was a prospective study of patients with zone V flexor injuries who presented to the casualty unit at CHBAH from 1st March 2018 to 30th April 2019. The demographic data were analysed, and the pre-operative clinical examination findings were compared to the definite intra-operative findings. The latter was to assess the accuracy of the pre-operative clinical examination findings of the orthopaedic registrars. One-sample test for proportion was used to assess if the difference between the pre-operative clinical examination findings and definite intra-operative findings was statistically significant.

Results: Zone V flexor injuries occur predominantly in males and in people less than forty years of age. The leading causes of these injuries in our setting were homicide and accidental injuries. These injuries occurred mainly in the employed, contract workers and students. Furthermore, they occur on the right upper limb and dominant side of the patients. Alcohol intake was a significant factor for the causes of these injuries.

Forty-eight percent and thirty-six percent of the zone V flexor injuries in our study were spaghetti wrists injuries and ulna triad injuries respectively. Concurrent injuries to the radial and ulna arteries were rare but lacerations of either of these arteries were common.

The overall accuracy of pre-operative clinical examination of zone V flexor injuries by orthopaedic registrars was 77.8%. The missed diagnosis of lacerated tendons, nerves and arteries were high. The accuracy of diagnosing partial injuries of tendons, nerves and arteries was very low. The rate of inaccurate diagnosis of flexor digitorium superficialis (FDS) tendons was higher than that of flexor digitorium profundus (FDP). Flexor carpi ulnaris (FCU) tendon, ulnar nerve and ulna artery had the highest rate of inaccurate diagnosis of pre-operative examination among the tendons, nerves and arteries, respectively.

CONCLUSION: There was a significant difference between pre-operative clinical examination and intra-operative findings. The accuracy of the clinical examination can be improved by enhancing the adequate knowledge and clinical skills of the examining doctor as well as carrying out the clinical examination in a pain-free, calm and co-operative patient. There should be a high index of suspicion for exploring zone V flexor injuries.

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NOMENCLATURE

A and E: Accident and Emergency

APL: Abductor pollicis longus

CEO: Chief Executive Officer

CHBAH: Chris Hani Baragwanath Academic Hospital

CMC: Carpometacarpal

DIPJ: Distal interphalangeal joint

FCR: Flexor carpi radialis

FCU: Flexor carpi ulnaris

FDP: Flexor digitorium profundus

FDS: Flexor digitorium superficialis

FPL: Flexor pollicis longus

IP: Interphalangeal

MCP: Metacarpophalangeal

MCPJ: Metacarpophalangeal joint

PIPJ: Proximal interphalangeal joints

PL: Palmaris longus

QOL: Quality of life

SAPS: South African Police Service

WITS: University of the Witwatersrand

CHAPTER 1

1 INTRODUCTION AND LITERATURE REVIEW

1.1 BACKGROUND

The zone V flexor region is densely packed with 12 tendons, three nerves and two major arteries (1). Zone V flexor injuries have a potential debilitating consequences and effects such as impaired hand dexterity, poor quality of life (QOL) of patients (1–3), prolonged sick leave (1,3), with concomitant loss of productivity (3) and in some instances multiple surgeries (4).

There are numerous literature and ongoing studies on the management of zone V flexor injuries including surgical techniques (5), coverage of soft tissue defect (6) and rehabilitation protocol (7,8). Some studies have been done to assess the functional outcome of patients who have sustained zone V flexor injuries and spaghetti wrist (5,9–12). However, there is very limited information on the diagnostic accuracy of clinical examination of these injuries. Clinical examination of these injuries gives the operating surgeon an idea of the injured structures. More often than not, the surgeons discover a completely different intra-operative findings than the documented clinical examination findings (13). This greatly interferes with theatre time planning and utilisation resulting in increased number of cancellation of cases. In some instances some injuries are missed in the emergency department (14), and patient is sent home only to come back later with hand dysfunction.

Throughout literature, there has been few studies done to assess the accuracy of clinical examination of injuries to the upper limb and the hand in general, (15–18) with only a single study carried out to assess the diagnostic accuracy of clinical examination in only zone V flexor injuries (19). This study was carried out by Gibson et al. from January 1993 to June 1994 and reported in 1999. This study was limited because the majority of the findings were based on a retrospective review with its inherent inadequate records.

This prospective study sought to assess the accuracy of the pre-operative clinical examination of zone V flexor injuries by orthopaedic registrars in the emergency department or casualty and to analyse the demographic data of patients who presented with zone V flexor injuries. It will report on the accuracy of predicting injuries to anatomical

structures in zone V flexor region and will provide the rich empirical data for surgeons on how accurate and reliable pre-operative clinical examination of zone V flexor injuries by orthopaedic registrars are.

1.2 LITERATURE REVIEW

1.2.1 Anatomy of zone V flexor region

Zone V flexor is anatomically defined as the region from the proximal end of the carpal tunnel to the musculotendinous junction in the forearm (20) (see Figure 1.1). In terms of landmarks, it is defined as the region from the distal wrist crease to the flexor musculotendinous junction in the forearm (21). It must be noted that the locations of the musculotendinous junction of the different muscle groups are at different levels in the forearm.

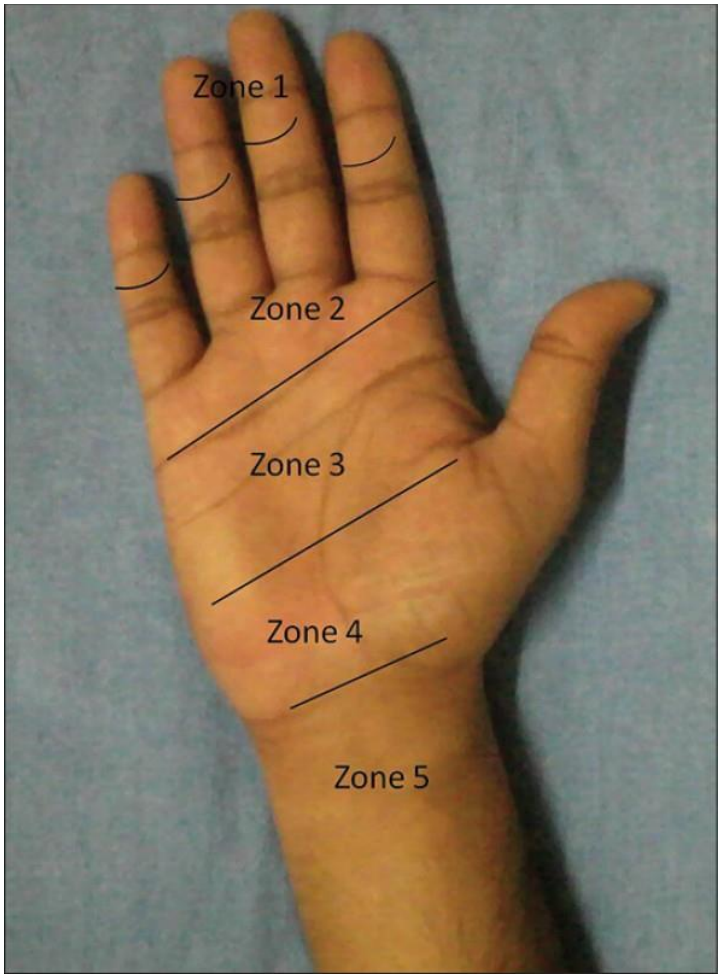

Figure 1.1: Showing the landmarks of the different zones of flexor region of the hand (20).

Zone V flexor region contains numerous and critical tendons, nerves and arteries (22,23), which are vital to the proper and meaningful function of the human wrist, fingers and the hand in general. Injuries to these anatomical structures could be very devastating to the patient and impair the proper functioning of the patient's hand (1–3). The following structures are found in zone V flexor region:

(i) Tendons are:

- Flexor carpi radialis
- Flexor carpi ulnaris
- Flexor pollicis longus
- Flexor digitorium superficialis to the index finger
- Flexor digitorium superficialis to the middle finger
- Flexor digitorium superficialis to the ring finger
- Flexor digitorium superficialis to the little finger
- Flexor digitorium profundus to the index finger
- Flexor digitorium profundus to the middle finger
- Flexor digitorium profundus to the ring finger
- Flexor digitorium profundus to the little finger
- Palmaris longus

(ii) Nerves are:

- Median nerve
- Ulnar nerve
- Superficial radial nerve

(iii) Arteries are:

- Radial artery
- Ulna artery

The tendons of the flexor carpi ulnaris (FCU) and flexor carpi radialis (FCR) are the most medially and laterally palpable tendons respectively on the volar surface of the distal forearm (22,23).

The flexor digitorium superficialis (FDS) muscle gives off four long tendons near the wrist (as shown in Figures 1.2 and 1.3) and travels through the carpel tunnel to insert into the bases of the middle phalanges of the index, middle, ring and little finger (22,23). Flexor digitorium profundus (FDP) muscle also gives off four tendons which run down the forearm through the carpel tunnel to the bases of the distal phalanx of the index, middle, ring and little finger (22,23).

The radial and ulnar arteries are the principal arteries of the forearm, wrist and hand (22,23). The median, ulnar and superficial radial nerves supply the muscles of the anterior forearm, wrist and hand (22,23). The median nerve become superficial by passing between the tendons of the flexor digitorium superficialis and flexor carpi radialis near the wrist where it is very vulnerable to penetrating injuries. The ulnar nerve lies lateral to the pisiform bone and superficial to the flexor retinaculum: at this anatomical location, it is exposed and very vulnerable to injuries such as stab and cut wounds (22,23).

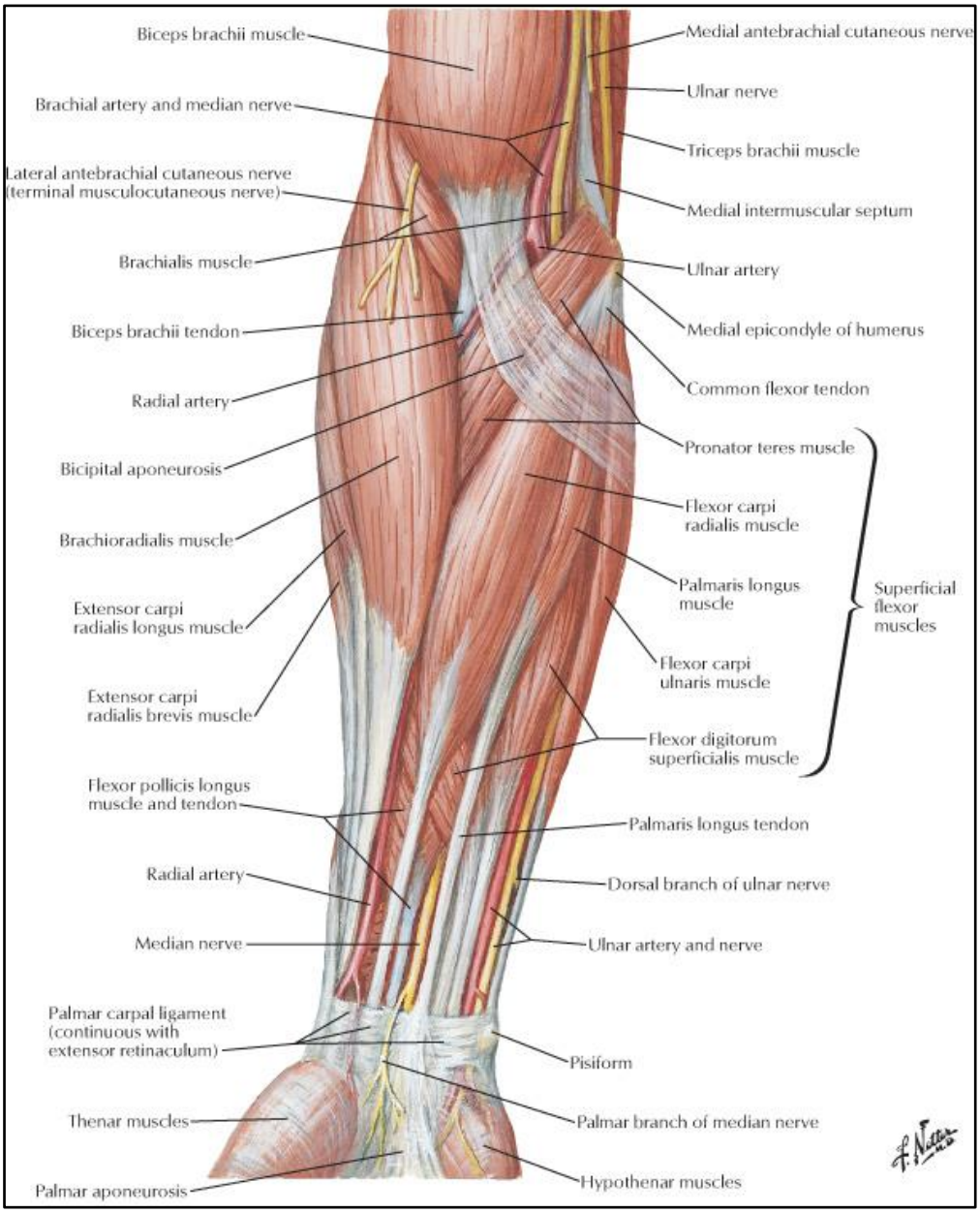

Figure 1.2: Anatomical figure showing the various tendons, arteries and nerves in the forearm and zone V (adapted from F. H. Netter) (24).

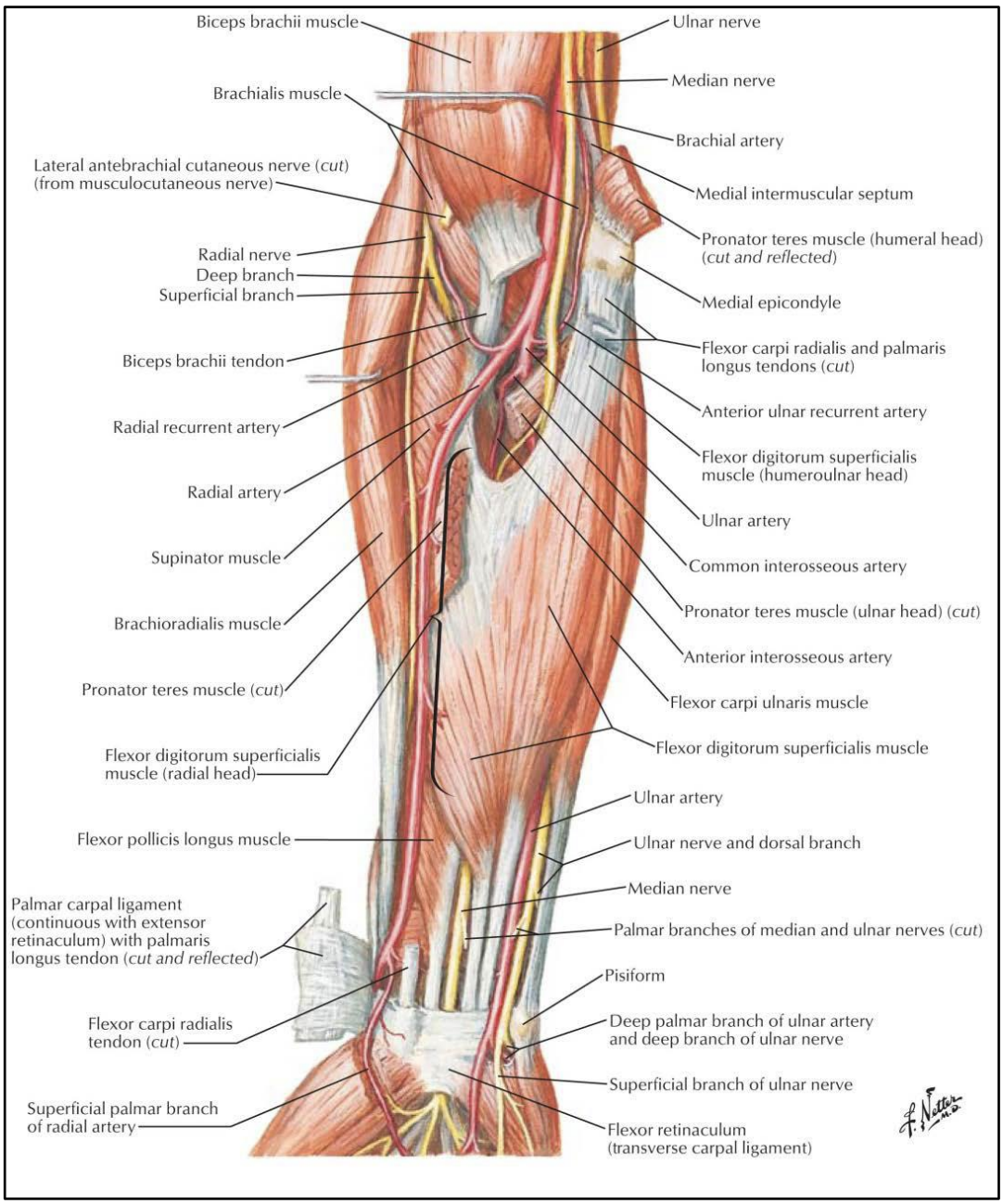

Figure 1.3: Anatomical figure showing a deeper anatomy of the tendons, vessels and nerves in the forearm (adapted from F. H. Netter) (24).

1.2.2 Zone V flexor injuries

Zone V flexor region is densely packed with tendons and neurovascular structures which makes its injuries very devastating with notably impaired functional outcome (3,4,26). The superficial location of the tendons and neurovascular structures in zone V flexor region with its widely exposed surface area makes it increasingly vulnerable for penetrating, accidental, homicidal and suicidal injuries (4,27). Directly underneath the volar side of the wrist, there are 12 tendons, two major nerves and two arteries which are superficial and very vulnerable to injuries (4,7,27,28). Below is a picture of a patient (see Figure 1.4) who presented at the Chris Hani Baragwanath Academic Hospital (CHBAH) with a zone V flexor injury, with multiple tendon and nerve injuries resulting in loss of cascade of the fingers.



Figure 1.4: Figure showing a zone V flexor injury with loss of the normal cascade of the fingers.

1.2.3 Spaghetti wrist

Spaghetti wrist is a variant or subtype of zone V flexor injury. It is also known as “full house syndrome” or “suicide wrist”. The definition of zone spaghetti wrist has evolved over the period of time. Puckett et al. described a minimal definition of spaghetti wrist as volar wrist laceration with three completely transected structures (tendon, nerve or vessel) (28). Kabak et al. defined spaghetti wrist as an extensive volar wrist laceration in which 10 structures are injured including tendons and at least one major artery and one major nerve (27). Kumar-Kempelingaiah et al. defined spaghetti wrist into a more complete

perspective. They defined it as “extensive volar wrist laceration occurring between the distal wrist crease and the flexor musculotendinous junction with an involvement of a minimum of three completely transected volar structures (nerve, artery and tendon) to at least 10 structures with or without one or more extensor tendons and bones (25). Below is an example of a spaghetti wrist (see Figure 1.5), this patient wrist injury was explored in the Hands unit at CHBAH.



Figure 1.5: Figure demonstrating spaghetti wrist with numerous tendons and a nerve injury.

Spaghetti wrist can be very extensive to involve as many as 12 tendons, two major arteries and two major nerves (28). Spaghetti wrist is noted for its severe incapacitating and disabling effects on the functioning of the hand, quality of life and productivity of patients who sustain such injury (1–4).

In reviewing literature, there are two common patterns of zone V flexor injuries and spaghetti wrists that are highlighted (7,10,11,25). They are the ulna-triad injures and radial-triad injuries. Ulna triad injuries occur to the FCU, ulna nerve and ulna artery in the same wrist or forearm. Radial sided injuries occur to the FCR, palmaris longus (PL) and median nerve in the same wrist and forearm. The simultaneous injuries to both ulna and median nerves are documented to highlight the severity of the injury and level of prognosis

for the patients (29). Concomitant injuries to both the radial and ulna arteries are also well documented (11,29).

1.2.4 Demographics of patients with zone V flexor injuries

The demographics of patients who sustain zone V flexor injuries vary from one study to another. Different studies also share some similar demographic characteristics.

A. Age

Literature clearly demonstrates that zone V flexor injuries and spaghetti wrist occur predominantly among the youth with the mean and median age being in the youthful category. Raza et al. reported that the average age of 27 years with the age range of 17-53 years in the study of thirty-one patients who sustained zone V flexor injuries (30). Kumar-Kempelingaiah et al. reported age range of 3 - 73 years with a mean age of 27.5 years, with 80% of patients under the age of forty years in their study of 198 patients who sustained spaghetti wrist over a period of eleven years (25). Kabak et al. also reported an average of 30.7 years with a range of 16 - 42 years (27). Puckett et al. in their study of patients with extensive volar wrist lacerations also reported an age range of 1-61 years with a mean and median ages of 22 years and 19 years respectively, with 33 out of the 37 patients (89.2%) under the 40 years of age (28). Gibson et al. also reported a mean age of 27 years with an age range of 14 - 61 years in his description of patients who sustained a zone V wrist laceration (19). Chin et al. reported a mean age of 29.0 years in a retrospective review of 60 patients who sustained a spaghetti wrist (26). Ashfaq et al. also reported a mean age of 27.1 years in a study sample of 44 patients who sustained glass injury to the wrist and hand (15). Mafi et al. also found the mean age of the 124 patients in his study to be 27.5 years (29).

B. Gender

Zone V flexor injuries and spaghetti wrist occurs predominantly in males but the ratio differs in different studies. Raza et al., Kumar-Kempelingaiah et al., Kabak et al., and Puckett et al. reported a male to female ratio of 2.4:1, 4.8:1, 2:1 and 3.6:1 respectively (25,27,28,30). Gibson et al. and Chin et al. also reported a male to female ratio of 4:1 and

2.2:1 respectively (19,26). The percentage of males in Ashfaq et al., Mafi et al.' and Yazdanshenas et al.'s studies were 79.5%, 92.8% and 89% respectively (11,15,29).

C. Mechanism of injury

Various studies reported similar mechanisms of injury with variable preponderance of particular mechanisms of injury. The various mechanisms of injury reported were assault (homicidal), accidental, industrial injury, parasuicide and self-inflicting when angry. Puckett el al. reported that the mechanism of injury of 27 out of 37 patients was accidental injury with two suicidal attempt and three industrial injury (28). Raza et al. reported that 80% of their cases were accidental, 10% were suicidal and 10% were homicidal (assault) (30). Kumar-Kempelingaiah et al. in their study found out that 39.4% of their patients were assaulted (homicide) and 15.1% were accidental injuries, 14.6% were industrial injuries 9.1% were suicide attempts, 3.5% were gunshot injuries and 7.5% were power saw injuries (25). Chin et al. also reported that accidental glass lacerations, knife wounds and suicide attempts were the mechanism of injuries for 61.0%, 23.7% and 8.5% of the spaghetti wrist injuries respectively (26). The top three mechanisms of injury for spaghetti wrist are accidental, assault and glass injury (31).

Glass injuries accounted for 70%, 81.5%, 68.7%, 14% and 15% of the patients in Raza et al., Puckett el al., Tuncali et al., Kabak et al. and Kumar-Kempelingaiah et al.'s studies respectively (25,27,28,30,32). However, the objects causing the injury ranged from glass window, knife, gunshot, fish tank, sharp machine cut, razor blade and cutlass (25,27,28,30,32).

Most cases of self-inflicting injuries usually occurred when the patient was angry and typically punched the arm through a glass window. Kabak et al. also reported that nine out of 21 patients injured themselves by punching a window while drunk (27). This demonstrated that alcohol was a significant causative factor in his cohort of patients.

D. Site of injury

The site of injury in Zone V flexor injuries, spaghetti wrist and upper limb injuries differs from one study to the other. Raza et al. study reported that 68% of the zone V flexor injuries occurred on the left while 32% occurred on the right (30). Kumar-Kempelingaiah

et al. also reported that 55% of the spaghetti wrist occurred on the left while 45% occurred on the right (25). Dehghani et al. reported that 68% of the upper limb injuries in his study occurred on the right (16). Ashfaq et al. also reported 68.2% of glass injuries to the hand and wrist in his study occurred on the right (15). Mafi et al. reported 75% of right hand involvement (29). Yazdanshenas et al. documented that 83.6% of the injuries in their patients occurred on the right hand (11).

E. Site of injury in relation to the dominant hand

Only Kabak et al. study described the involvement of the dominant upper limb. They reported 52% of dominant upper limb involvement (27).

1.2.5 Assessment of accuracy of pre-operative clinical examination of zone V flexor injuries

In review of literature, there is only one documented study in which the accuracy of clinical examination of only zone V flexor injuries was assessed. This was carried out by Gibson et al. (19). This study was conducted in two phases. The first phase was a retrospective study in 1993, where accuracy of pre-operative clinical examination of zone V flexor injuries in 33 patients was examined. The second phase was a prospective study of 17 patients with zone V flexor injuries who were examined by four different groups of doctors with varying level of experience in hand surgery. The second phase was carried out to determine whether experience in hand surgery influence the accuracy of clinical examination in such injuries. The limitation of Gibson et al.'s study was that the majority of the patients were in the retrospective phase and had incomplete records. Other studies examined the accuracy of clinical examination of the hand and upper limb injuries in general.

A. Accuracy of clinical examination

Accuracy of clinical examination was defined as the condition where the intraoperative findings were exactly the same as clinical or pre-operative findings for an anatomical structure.

Gibson et al. reported that only 13% of the clinical examination of zone V wrist injuries was 100% accurate and the level of the accuracy did not correlate so well with the experience of the examining doctor. They also found that 50% of the clinical examinations had three or more errors and 20% of the clinical examinations had five or more errors (19).

Patel et al. reported in their study that hand surgeons accurately diagnosed 84% of complete tendon injuries and 94% of complete nerve injuries in hand lacerations (i.e. from zone I to V), however, it is of interest and importance that the accuracy of diagnosing median, ulna and common digital nerve injuries were 100%. The error in diagnosing nerve injuries was in the diagnosis of divisions of the digital nerves (18). Nassab et al. also reported that hand surgeons accurately diagnosed 68.2% and 78.8% of flexor tendon and nerve injuries respectively (17). However, both Patel et al. and Nassab et al. studies assessed accuracy of clinical examination in hand lacerations including all zones of both flexor and extensor regions (17,18) but not the diagnostic accuracy of only zone V flexor region which this study is seeking to assess.

Dehgani et al. reported an error rate of 14% in diagnosing lesions on the volar side of the upper limb injuries with a mean error rate of determining structural lesions of 26.9%. There was also an error rate of 43.7% and 41.8% for diagnosing arterial and nerve lesions (16).

B. Missed diagnosis

Missed diagnosis of a lacerated structure is defined as the condition where an anatomical structure was found to be lacerated intra-operatively but assessed pre-operatively as intact or partially injured. Missed diagnosis of a partially injured structure is defined as the scenario where an anatomical structure was found to be partially injured intra-operatively but was assessed pre-operatively as intact.

Gibson et al. found that 205 items in 97 examinations were assessed to be intact before surgery but were found to be lacerated intra-operatively and needed a repair. It must be noted that about 17 patients were each examined by four different groups of doctors therefore adding another variable to their study. There was an average of 2.1 structures per examination that was missed. Ulna artery injuries were frequently missed in their study. Injuries to FCU and FDS to the index finger were also frequently missed. Median and

ulnar nerve injuries had the lowest error rate (19). Nassab et al. also reported that 31.8% and 21.2% of flexor tendon and nerve injuries respectively were missed by hand surgeons (17).

Patel et al. reported that hand surgeons missed 16% and 6% of complete tendon and nerve injuries respectively (18). Hand surgeons also missed four out of eight complete injuries of flexor carpi ulnaris (FCU), flexor carpi radialis (FCR) and extensor carpi ulnaris (ECU) tendon complete injuries (18). Both Nassab et al. and Patel et al. observed the difficulty in distinguishing between FDP and FDS of the fingers by accident and emergency doctors (17,18).

Provencher et al. findings illustrated that clinical examination underestimates the actual extent of glass injuries to the hand even when the pre-operative examination is performed by orthopaedic hand surgeons (13). When caution is not taken, missed diagnosis on pre-operative examination may end up as missed injuries where patients with median and ulnar nerves injuries are treated in an emergency department and discharged without formal exploration as reported by Morrison et al. (14).

C. Over diagnosis

Over diagnosis of an intact anatomical structure is defined as the condition where an anatomical structure was found to be intact intra-operatively but was assessed pre-operatively as lacerated or partially injured. Over diagnosis of a partially injured anatomical structure is defined as the condition where an anatomical structure was found to be partially injured intra-operatively but was assessed pre-operatively as lacerated.

Gibson et al. did not document his findings on the rate of overdiagnosis (19). Patel et al. reported that hand surgeons over diagnosed 10 tendons and 17 nerves as injured while they were found to be intact intra-operatively (18). Nassab et al. also reported that hand surgeons over diagnosed 13 nerve injuries and 9 tendon injuries (17).

1.2.6 Factors affecting accuracy of pre-operative clinical examination of zone V flexor injuries

The accuracy of pre-operative clinical examination findings of hand injuries differ among doctors, patients, one injury to another and in different studies. This also occur in zone V flexor injuries. A number of factors that affect the accuracy of pre-operative clinical examination of hand injuries are explained below.

A. Clinical examination skills of examining doctors

The clinical examination skill is very important in ensuring maximum accuracy when examining injured structures. A typical example is the examination of flexor digitorium profundus and flexor digitorium superficialis tendons. Knowledge of clinical examination is very essential in differentiating injury to FDS from injury to FDP of the same finger. This is because each index, middle, ring and little finger has both FDP and FDS tendons. FDS flexes the proximal interphalangeal joint (PIPJ) and FDP flexes both PIPJ and distal interphalangeal joint (DIPJ). FDP can flex the PIPJ of a finger when FDS is injured, hence in examining the FDS, one needs to eliminate the effect of FDP and this require a special clinical examination. Lack of this clinical examination skill among other factors was the reason why 16 out of 26 FDS tendon injuries were missed by A and E doctors in Patel et al.'s study (18).

Another elaborate example is the use of Allen test in identifying vascular injuries. When this technique is not used, vascular injuries are missed because of its numerous collaterals and adequate back flow through palmar arches (17).

B. Level of knowledge of the functional anatomy

In order to have an accurate assessment of structures injured in any laceration, the examining doctor needs great knowledge of the anatomical structures and their function. This helps the examining doctor to have a high index of suspicion therefore improving accuracy. The difference in the knowledge of anatomy of the zone V flexor region accounted for the higher level of accuracy of hand surgeons than A and E doctors in diagnosing zone V flexor injuries in Nassab et al.'s study (17).

Murphy et al. also found that 80% of senior house officers did not know the insertion of FDS and 62% also did not know the tendon that lies over the median nerve in their first week in Accident and Emergency (A and E) department (33). Knowledge of the functional anatomy of the hand and wrist also helps in identifying associated injuries because of the proximity of the structures. This can result in observation error if structures are not assessed individually.

C. Lack of thorough examination

It has been proposed that once an examining doctor identifies a significant structural lesion that will require repair, he or she no longer examine for other structural injuries comprehensively because the assumption is made that the patient will definitely be sent to theatre for exploration (18).

D. The case of partial tendon injury

Partial tendon injury is difficult to diagnose (34). This is because of the residual motor function mimicking an intact anatomical structure (15). There has been no single study where a partial injury of even a nerve or tendon was accurately diagnosed.

E. Observer error

Observer error is the difference between a measured value of a quantity and its true value. It can be attributed to the measurement process or observation (35,36). In assessing hand injuries, the examining doctor normally interprets the patient's response to the instruction given and accurate judgement of the doctor is required in measurement. This interpretation can be inaccurate introducing an observer error. Examiners can report different findings on serial examinations of the same injury.

In addition, experienced examiners normally have an expectation and that brings bias into the examination because the examiner knows the proximity of the anatomic structures in the injured region, assumptions are made and each structure is not examined objectively and individually (19). This is a typical example of observer bias, also introducing observer error.

F. Patient factors

The accuracy of the clinical examination is determined largely by the patient's response to instructions by the examining doctor. Therefore, any factor that influences the patient's response will invariably affect the accuracy of the clinical examination. These factors include level of co-operation, anxiety, pain, alcohol intoxication and language barrier.

Primary repair of flexor tendons has better functional recovery than delayed repair (8,30). There is also far better outcome with primary repair of nerves as compared to secondary repair (30), especially in young patients (37), but not in older patients (11,38). There is therefore, the need for early accurate pre-operative clinical diagnosis and exploration to achieve a better outcome.

1.3 Study Aim and objectives

The aim of this study was to assess the diagnostic accuracy of pre-operative clinical examination in zone V flexor injuries.

The objectives of this study were to:

a. To analyse the demographic data of patients who presented with zone V flexor injuries in Chris Hani Baragwanath Academic Hospital (CHBAH).

b. To assess the accuracy of pre-operative examination of orthopaedic registrars with regards to zone V flexor injuries.

1.4 STUDY RELEVANCE

This study will help identify the errors of clinicians, especially orthopaedic registrars in the clinical examination of zone V flexor injuries, the factors that cause these errors and find ways to improve the clinical examination of clinicians in these injuries. Secondarily, this study will also aid to assess how pre-operative clinical examination findings can affect theatre time planning and utilisation.

CHAPTER 2

2 METHODOLOGY

This chapter describes how the study was designed and carried out.

2.1 Research Question

What is the diagnostic accuracy of pre-operative clinical examination in zone V flexor injuries?

2.2 Null Hypothesis

There is no difference between pre-operative and intraoperative findings of zone V flexor injuries.

2.3 Research Design

The study was a prospective study of adult male and female patients from the ages of 18 years and older who presented with a zone V flexor injury at the emergency department or casualty unit of CHBAH. The duration of the study was from 1st March 2018 to 30th April 2019. Ethics clearance had been obtained from the Human Research Ethics Committee (HREC), Medical, University of the Witwatersrand (Clearance Number: **M1711120**)

2.4 Materials and Methods

Patients with zone V flexor injury who reported to the casualty unit at Chris Hani Baragwanath Academic Hospital (CHBAH) were counselled and consent was obtained prior to inclusion in the study. The patients were interviewed and examined by the orthopaedic registrars. The demographic data were documented as shown in Appendix A. The pre-operative clinical examination findings were documented as shown in Appendix B. As per our protocol at CHBAH, patients were counselled and informed consent was obtained for exploration and repair of tendons and neurovascular structures. The patients were then sent to the theatre and the operating doctors documented their intra-operative findings (see data collection in Appendix C).

2.5 Sample size and selection criteria

The study sample consisted of all patients who presented at CHBAH with zone V flexor injuries during the study period, met the inclusion criteria and gave consent to be part of the study. Only patients whose data collection forms were completely filled were included in the study. The sample size was 56 patients and 58 injuries were examined.

The inclusion criteria for the study were patients with injuries in the zone V flexor region with laceration extending beneath the subcutaneous tissue and presentation within 24 hours after sustaining the injury. The exclusion criteria were patients with previous wound exploration, mental disability, Glasgow coma score (GCS) of less than 15, crush injury, traumatic amputation, associated fractures, bites, and inability to give an informed consent.

2.6 Data Collection

The data collections sheets had three pages (see Appendices A – C). The first page (see Appendix A) consisted of questions pertaining to the demographics of the patient, mechanism of injury and gross description of the injury. This data was taken through face-to-face interview with the patient. This first page was documented by an orthopaedic registrar on call at the casualty unit. The second page (see Appendix B) was meant for pre-operative clinical examination findings. The orthopaedic registrar in casualty unit examines the patient and documents his or her pre-operative clinical examination findings on each anatomical structure examined. The third page (see Appendix C) was for definitive intra-operative findings. The operating doctor documented his or her definitive intra-operative findings on each anatomical structure.

2.7 Data Analysis

The raw data was entered on Microsoft excel and analysed using Stata version 15.0. The first objective sought to describe the demographic and clinical characteristics of the study participants. To achieve this, frequency, proportions and percentages were reported for all categorical variables such as sex, employment, site and dominant hand. For the numerical variable (e.g. age), mean and standard deviation were reported.

The second objective was to assess the accuracy of pre-operative findings. This was done by comparing the pre-operative clinical examination findings to the definitive intra-operative findings. Accuracy of diagnosing a lacerated, partial injury and an intact anatomical structure was assessed. These are explained below:

- The accuracy of diagnosing a lacerated structure pre-operatively was estimated for each anatomical structure. This was done by computing structures that were found to be lacerated intra-operatively and assessed clinically as lacerated. Missed diagnosis of a lacerated structure was also computed by finding out structures that were lacerated intra-operatively but were clinically assessed as either intact or partially injured.

- The accuracy of diagnosing a partial injured structure pre-operatively was also assessed for each anatomical structure. This was done by computing structures that were found to be partially injured intra-operatively and assessed clinically as partially injured. Inaccurate diagnosis of a partial injured structure was also computed by finding out structures that was partially injured intra-operatively but was assessed pre-operatively as intact or lacerated.

- The accuracy of diagnosing an intact structure pre-operatively was also assessed for each anatomical structure. This was done by computing structures that were found to be intact intra-operatively and assessed clinically as intact. Over diagnosis of an intact structure was also computed by finding out structures that were intact intra-operatively but was assessed clinically as either partially injured or lacerated.

The overall accuracy of pre-operative clinical examination was assessed. This was done by comparing the pre-operative findings to the definitive intra-operative findings for all the anatomical structures in all the 58 injuries examined. Accurate diagnosis was assessed as examination of an anatomical structure where the pre-operative finding was exactly the same as the intra-operative finding. The total number of accurate diagnosis was divided by the total number of examinations to get to the overall accuracy.

One-sample test for proportion was used to assess if there was a statistically significant difference between intra-operative and pre-operative clinical examination findings for lacerated, partial injured, intact and the entire anatomical structures in the 58 injuries examined.

2.8 Limitations

The sample size of the patients who presented to the casualty with zone V flexor injuries was small. Furthermore, some patients who were admitted, later refused surgery, were subsequently discharged and therefore, could not be included in the study. A few forms were not completed by the orthopaedic doctors at the casualty unit. The study was however extended for eight months to get to the sample size.

CHAPTER 3

3 RESULTS

The demographic data of the patients and information regarding the injury were analysed and stratified. The pre-operative clinical examination findings and intra-operative findings were analysed to assess the diagnostic accuracy of the pre-operative clinical examination.

3.1 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF PATIENTS

A total of 61 patients with zone V flexor injuries were admitted at CHBAH from 1st March 2018 to 30th April, 2019. The total number of patients enrolled in this study was 56 with 58 injuries clinically examined. Two patients had bilateral zone V flexor injuries. Five patients were excluded from the study due to the following reasons:

- Two patients later refused surgery after admission and thorough counselling, so they were discharged home.
- Two patients also had a Glasgow coma score of 14 and less and therefore could not be clinically assessed.
- One patient was also rushed to emergency theatre by trauma surgeons and orthopaedic doctors were called to carry out surgery on the patient without pre-operative clinical assessment.

The Tables and Figures below show the essential demographic characteristics of the patients who were enrolled in the study. These characteristics include age, gender, employment status, mechanism of injury, site of injury, dominant hand and the site of injury with regards to the dominant hand.

3.1.1 Gender and age of patients

Table 3.1 below summarises the number of males and females enrolled in the study and their age characteristics.

Table 3.1: Total number of males and females and characteristics of their ages.

Gender	***n* (%)**	**Age (yrs)** **Mean (SD)**	**Min Age**	**Median Age**	**IQR**	**Max Age**	**Overall (Both males and females)**
Male	45(80.4%)	32.5(10.6)	18	30	20 - 50	67	32.2
Female	11(19.6%)	31.2(10.7)	20	26	24 - 29	49	

IQR: interquartile rage, yrs: years; *n*: sample size.

The majority (80.4%) of patients enrolled in this study were males. The male to female ratio was 4.1:1. The median age for males (30 years) and females (26 years) was similar. However, there was much variability with regards to the median age for males (Interquartile range [IQR] = 20 – 50) compared with females (IQR = 24 -29). The mean age of the females was 1.3 years younger than the males. The mean age of the total patients was 32.2 years. Forty seven (47) out of the 56 patients were below the age of 40 years, constituting 83.9% of the patients.

3.1.2 Employment status of patients

The pie chart below (see Figure 3.1) illustrates the employment status of the 56 patients who were enrolled in the study. More than half (55.4%) of the patients were gainfully employed whereas 21.4% were unemployed. The majority of the patients were actively working, engaged in contract work or studying.

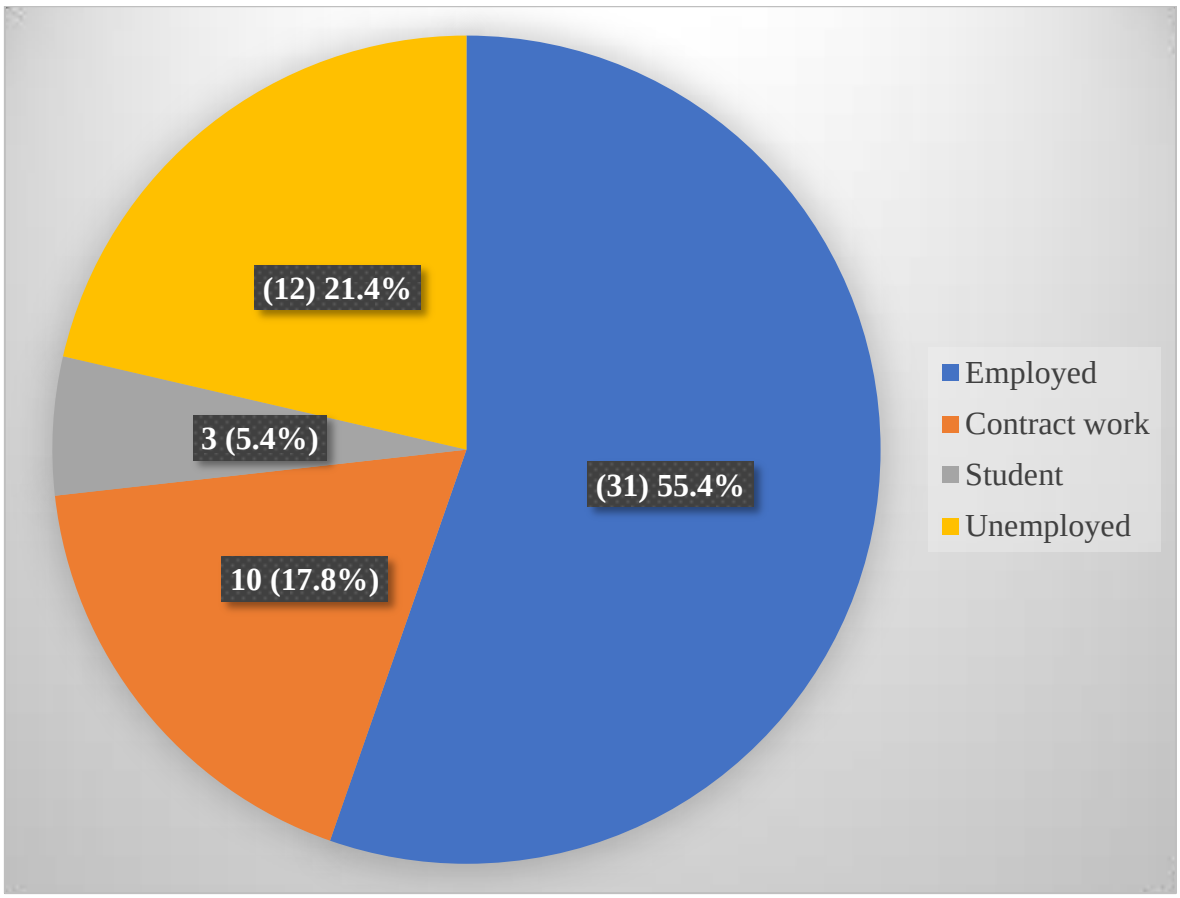

Figure 3.1: Employment status among the patients.

3.1.3 Mechanism of injury

Figure 3.2 illustrates the mechanism of injury in the 58 injuries. Assault was the leading cause of injury in the study population, followed by accidental injury, industrial injury, self-inflicted injury and parasuicide in descending order. The self-inflicted injuries occurred when the patients were angry and punched their hands through a glass window. Panga, broken bottle, knives and glass window were the tools used to assault the patients.

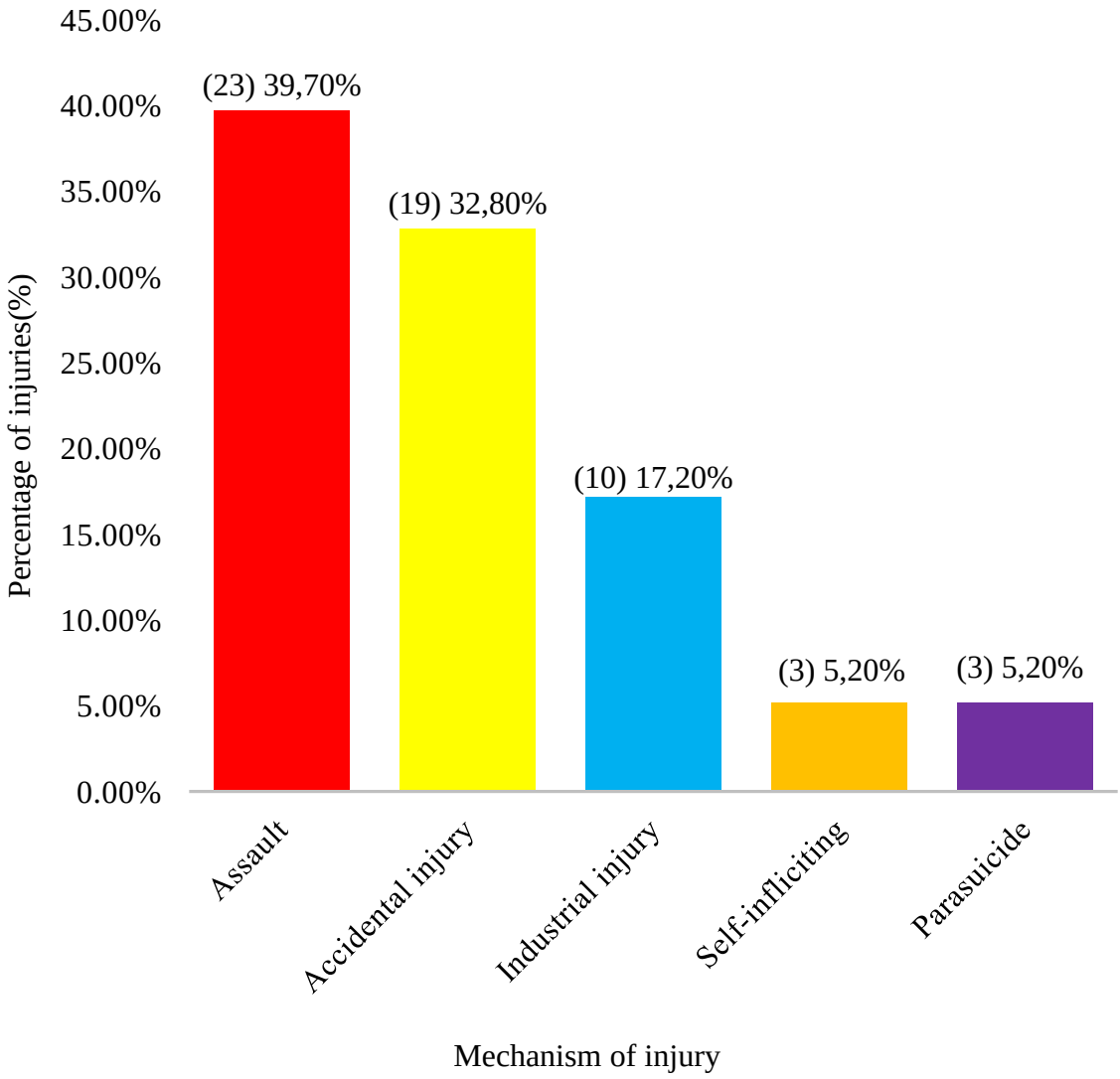

Figure 3.2: Mechanism of injury

3.1.4 Alcohol intake

Figure 3.3 describes the proportion of the patients who had admitted to having taken alcohol prior to sustaining the injury.

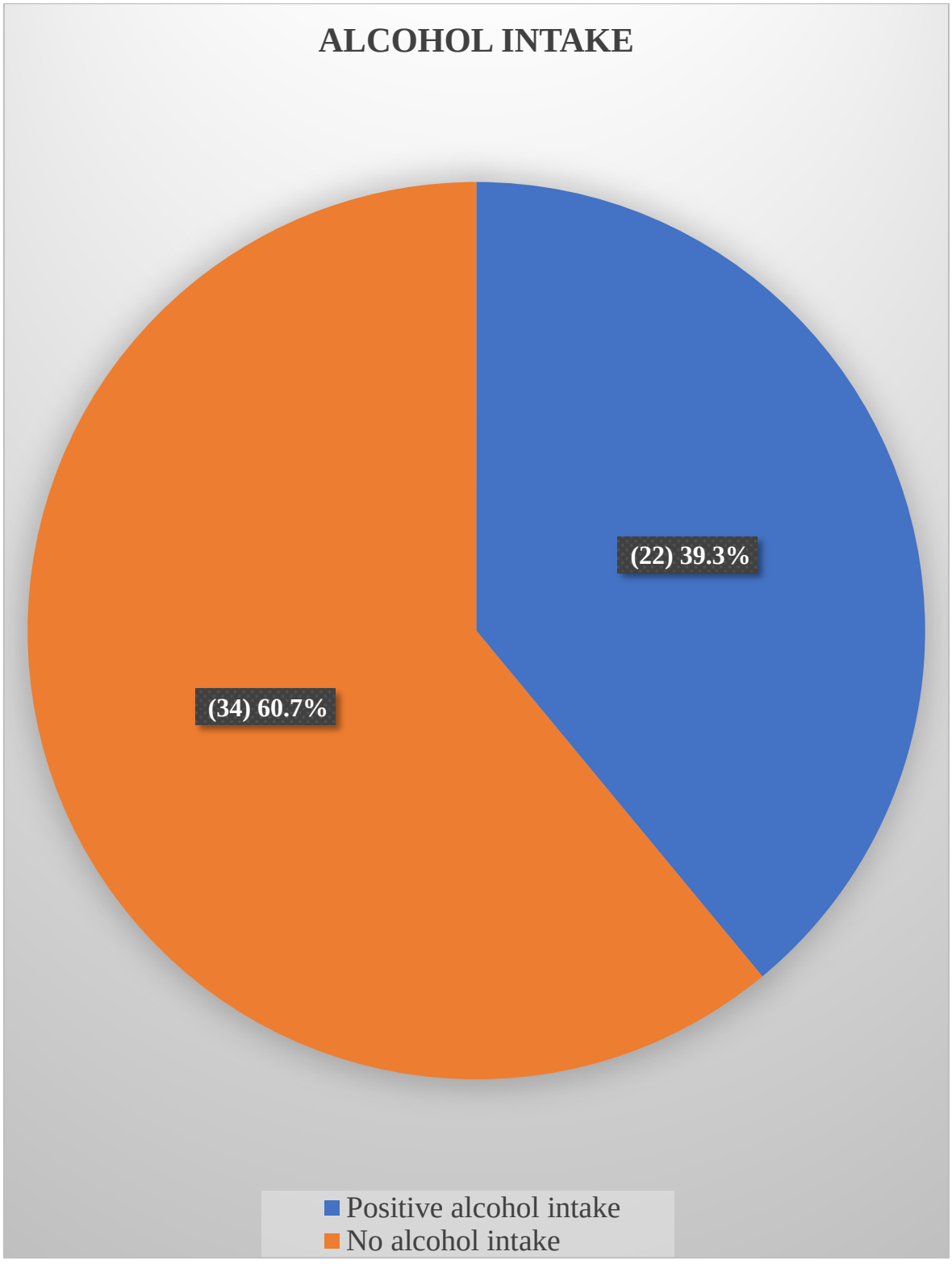

Figure 3.3: Alcohol intake among the patients.

Thirty nine percent (39.3%) of the patients admitted that they had taken alcohol when the injury occurred. In these 22 patients who had taken alcohol prior to sustaining the injury, the bar graph below (see Figure 3.4) demonstrates the mechanism of injury.

3.1.5 Mechanism of injury among patients who had alcohol intake

Figure 3.4 below illustrates the mechanism of injury among patients that admitted to consuming alcohol.

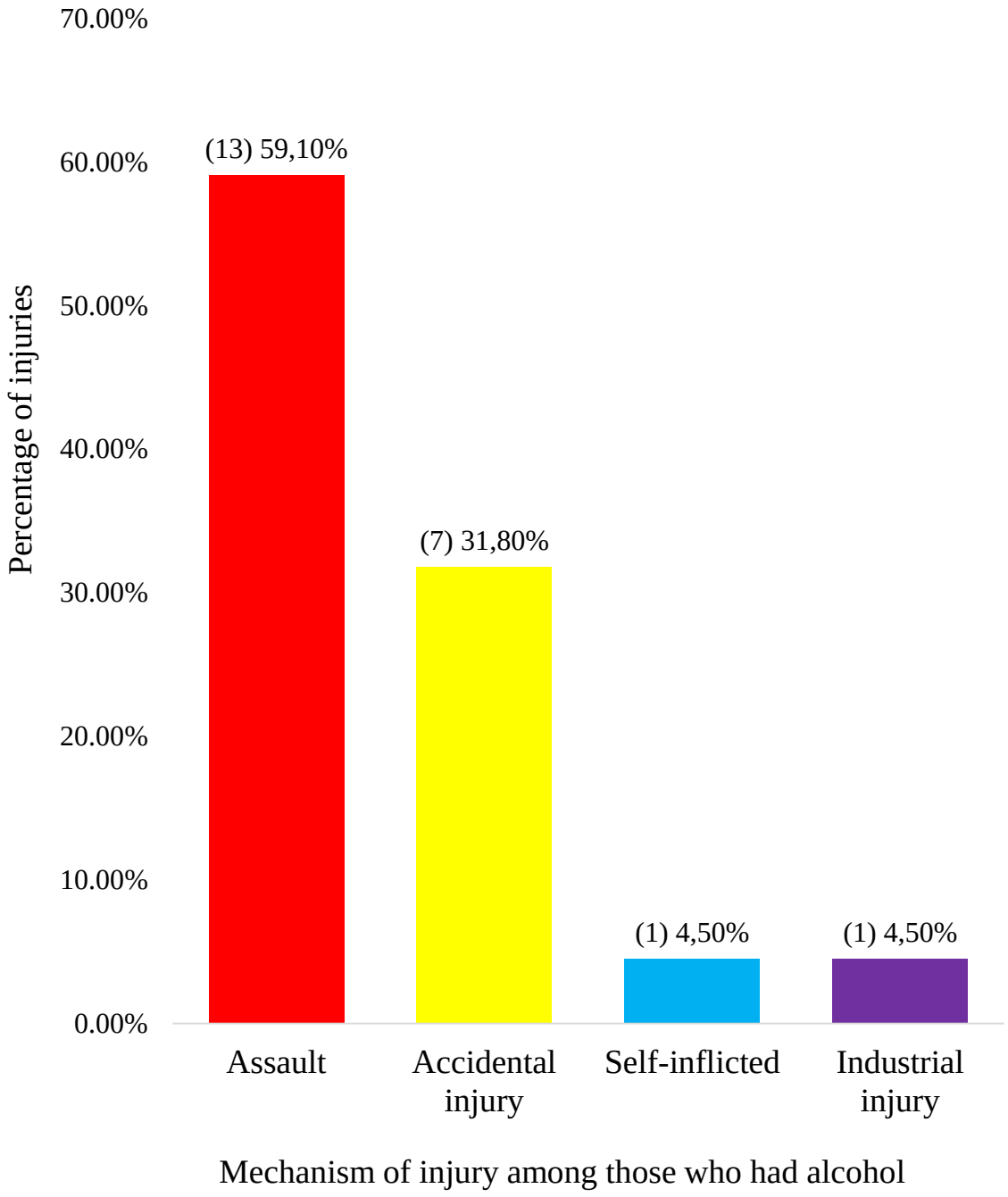

Figure 3.4: Mechanism of injury among patients who had alcohol.

The mechanisms of injury among patients who had alcohol were mainly assault and accidental injuries. Inferring from Figures 3.2 and 3.4, thirteen (13) out of the 23 patients (56.5%) who were assaulted had consumed alcohol and seven out of 19 patients (36.8%) who had accidental injuries had also consumed alcohol.

3.1.6 Day of injury

Figure 3.5: below illustrates the number of injuries that occurred on each day of the week.

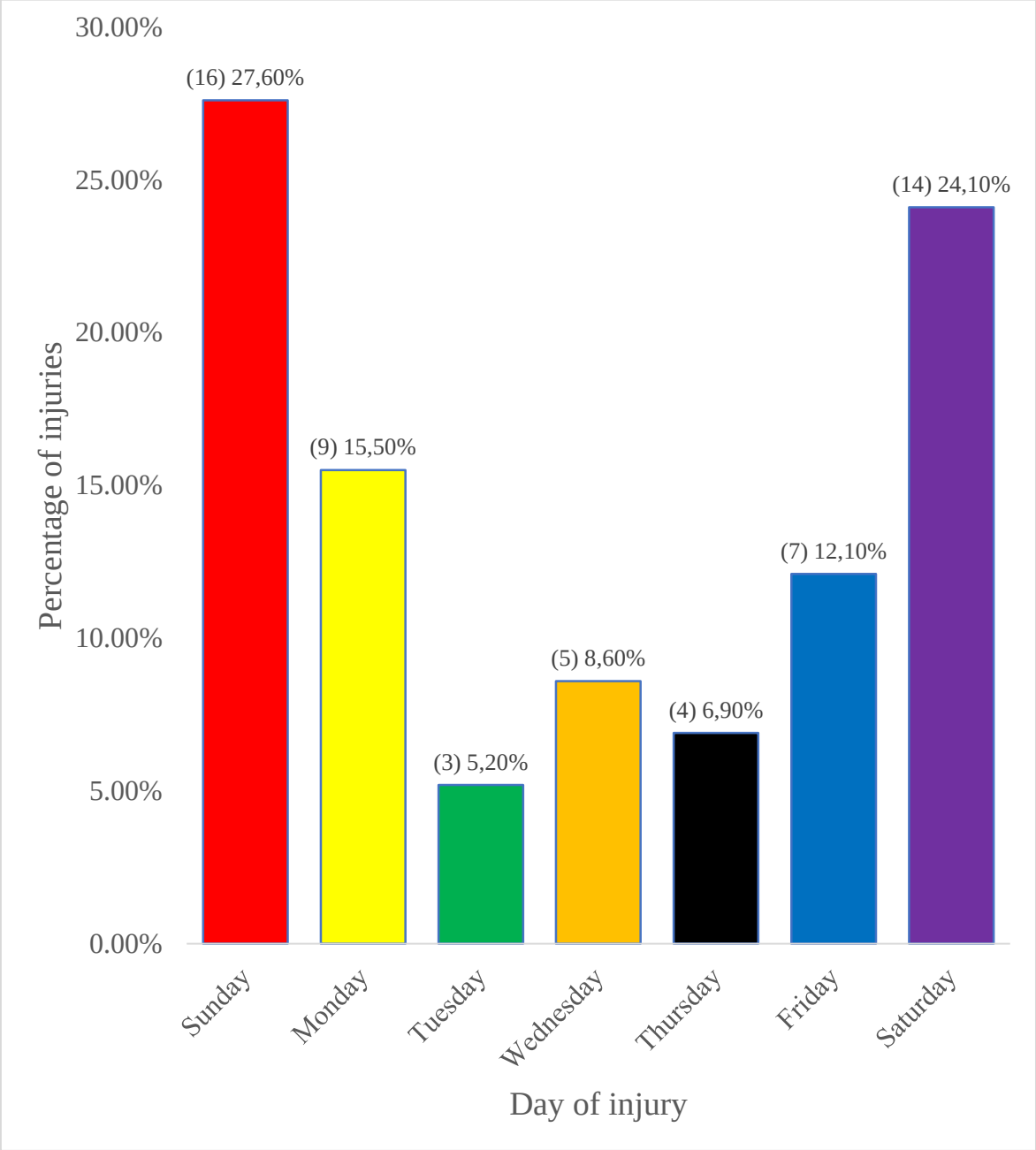

Figure 3.5: Frequency and percentage of injuries per day of the week.

The injuries peaked on Saturdays and Sundays. More than half of the injuries occurred on Saturdays and Sundays. More than sixty-three percent (63.8%) of the injuries occurred during weekends from Friday evening to Sunday night.

3.1.7 Site of injury

Figure 3.6 below show the site of the forearm where the injury occurred.

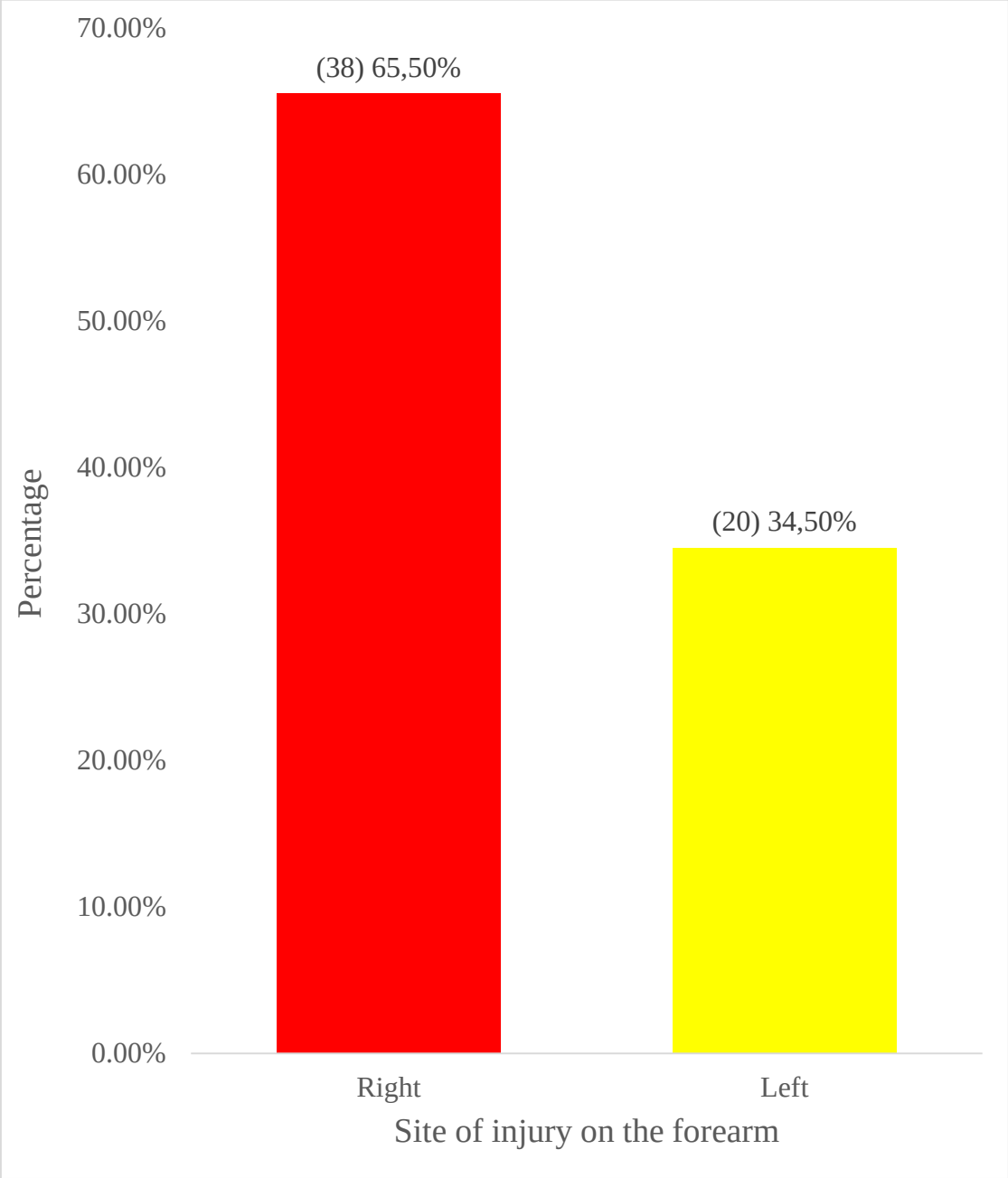

Figure 3.6: Frequency and percentage of injuries on the site of forearm.

Majority of the injuries (65.5%) occurred on the right hand compared to the left hand.

3.1.8 Patient's dominant hand

Figure 3.7 illustrate the dominant side of the patients.

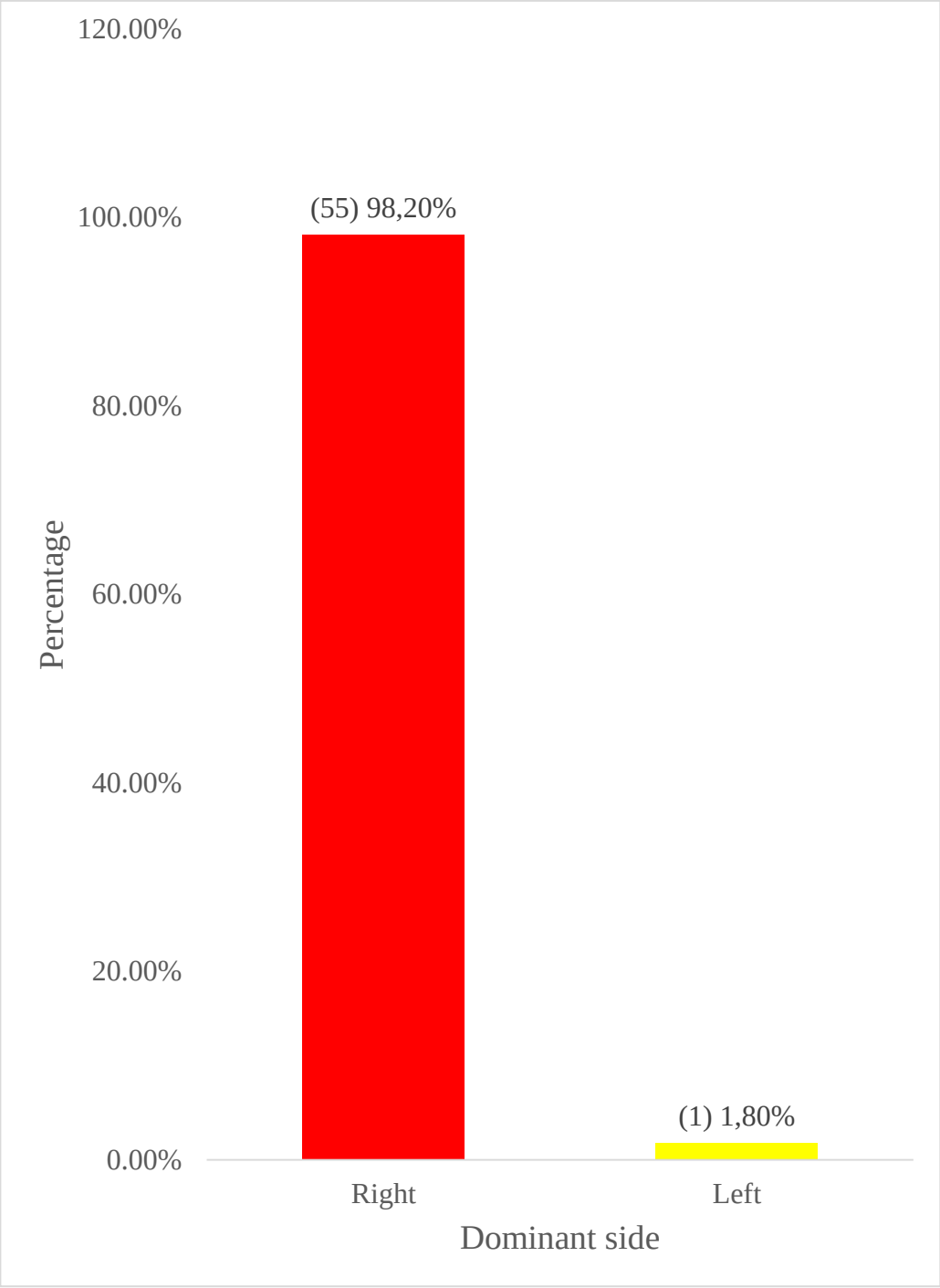

Figure 3.7: Frequency and percentage of dominant side of patients.

About ninety eight (98.2%) (55 out of 56) of the patients were right hand dominant.

3.1.9 Site of injury in relation to patient's dominant hand

Figure 3.8 below illustrates the frequency and percentage of the injuries in relation to the patient's dominant hand.

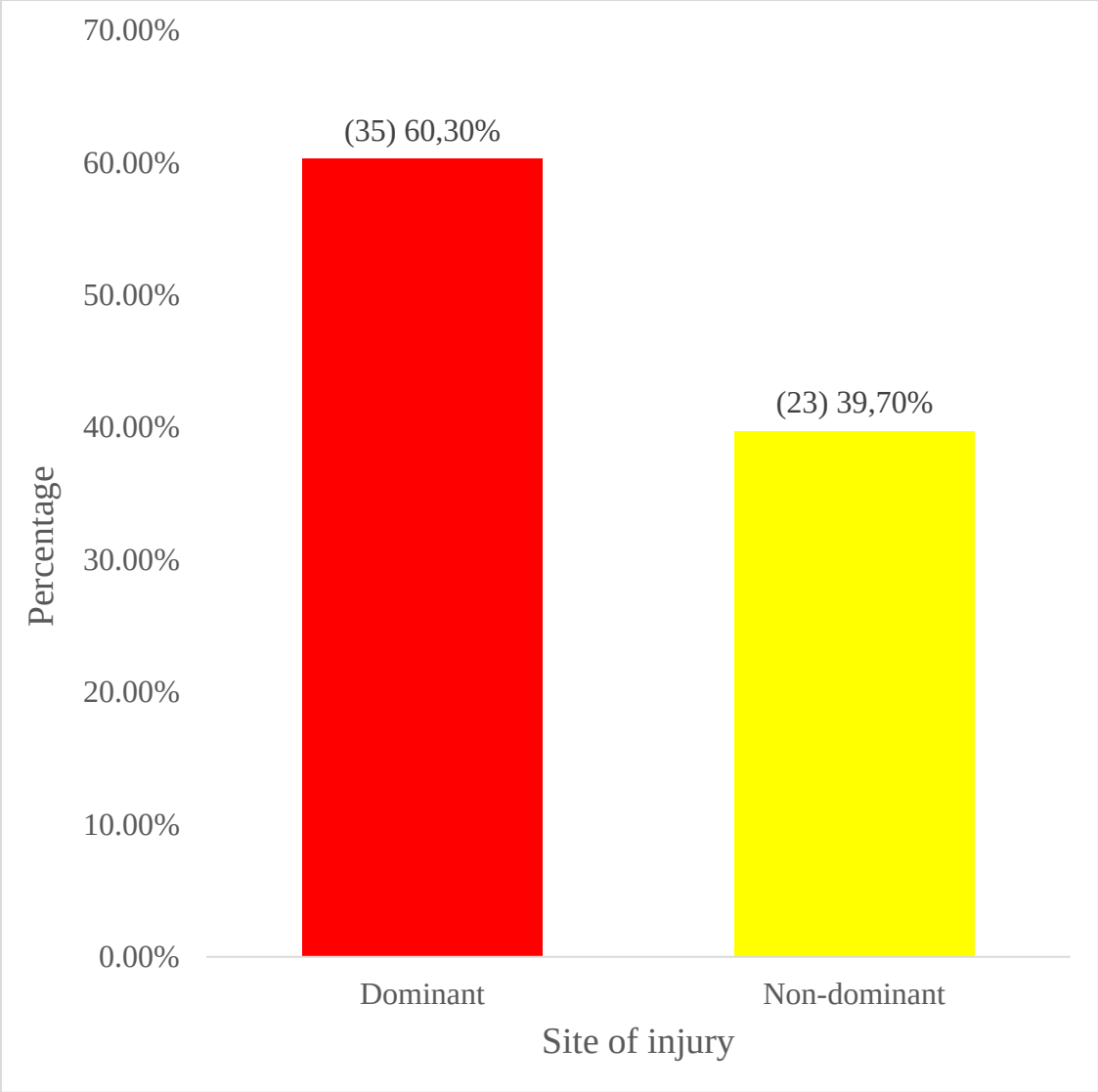

Figure 3.8: Frequency and percentage of injuries occurring on the dominant and non-dominant hand.

More than 60% of the injuries occurred on the dominant hand of the patient.

3.2 PRE-OPERATIVE CLINICAL EXAMINATION FINDINGS

Table 3.2 below summarises the pre-operative clinical examination findings in the 58 injuries with respect to each anatomical structure.

Table 3.2: Summary of the pre-operative clinical examination findings for each anatomical structure in all the 58 injuries examined.

Anatomical Structures	**Intact**	**Partial injury**	**Lacerated**
FCR	41	0	17
FCU	30	1	27
FPL	46	1	11
FDS index finger	42	3	13
FDS middle finger	47	3	8
FDS ring finger	29	6	23
FDS little finger	27	8	23
FDP index finger	44	1	13
FDP middle finger	47	1	10
FDP ring finger	36	4	18
FDP little finger	36	5	17
Superficial radial nerve	52	1	5
Ulnar nerve	28	5	25
Median nerve	39	9	10
Radial artery	54	1	3
Ulnar artery	43	0	15
Total	**641**	**49**	**238**

Two hundred and thirty-eight anatomical structures were assessed pre-operatively to be lacerated while 49 structures were assessed to be partially injured. FCU was the tendon that was most frequently assessed pre-operatively to be lacerated. Ulnar nerve was the nerve frequently assessed pre-operatively to be lacerated while ulnar artery was more frequently assessed clinically to be lacerated than radial artery. Below is a summary of the number of tendons, nerves and arteries assessed pre-operatively to be lacerated, partially injured and intact.

3.2.1 Summary of pre-operative clinical examination findings

Table 3.3 below illustrates the pre-operative clinical examination findings of all tendons, nerves and arteries in the 58 injuries examined.

Table 3.3: Summary of the pre-operative clinical findings for all tendons, nerves and arteries in the 58 injuries examined.

Anatomical Structures	**Intact**	**Partial injury**	**Lacerated**
Tendons	425	33	180
Nerves	119	15	40
Arteries	97	1	18
Total	**641**	**49**	**238**

3.3 INTRA-OPERATIVE FINDINGS

Table 3.4 below summarises the intra-operative findings of each anatomical structure in the 58 injuries operated.

Table 3.4: Summary of the intra-operative findings of each anatomical structure in the 58 injuries operated.

Anatomical structures	**Intact**	**Partial injury**	**Lacerated**
FCR	37	3	18
FCU	21	8	29
FPL	45	2	11
FDS index finger	39	4	15
FDS middle finger	40	5	13
FDS ring finger	30	1	27
FDS little finger	30	2	26
FDP index finger	42	4	12
FDP middle finger	42	3	13
FDP ring finger	36	5	17
FDP little finger	37	3	18
Superficial radial nerve	53	1	4
Ulnar nerve	31	7	20
Median nerve	38	6	14
Radial artery	52	0	6
Ulnar artery	32	1	25
Total	**605**	**55**	**268**

Intra-operatively, 268 anatomical structures were found to be lacerated and 55 were partially injured. FCU was the most frequently lacerated tendon followed by FDS to the ring and little finger respectively. FCU was again the most partially injured tendon. Ulnar nerve was the most frequently lacerated and partially injured nerve followed by median

nerve. There were only four cases and one case of lacerated and partially injured superficial radial nerve respectively. The ulna artery was frequently lacerated than the radial artery. The number of tendons, nerves and arteries that were found to be lacerated and partially injured are summarised in Table 3.5 below.

3.3.1 Summary of intra-operative findings

Table 3.5 below summarises the intra-operative findings of all tendons, nerves and arteries.

Table 3.5: Summary of intra-operative findings of all tendons, nerves and arteries.

Anatomical Structures	**Intact**	**Partial injury**	**Lacerated**
Tendons	399	40	199
Nerves	122	14	38
Arteries	84	1	31
Total	**605**	**55**	**268**

3.3.2 Summary of intra-operative findings (by percentage)

Table 3.6 below illustrates the percentage of all tendons, nerves and arteries in the 58 forearms that were injured (lacerated and partial injury).

Table 3.6: Summary of the intra-operative findings by percentage of total number of tendons, nerves and arteries that were injured (lacerated and partial injury).

Anatomical Structures	**Number of structures injured**	**Total number of structures**	**Percentage of Structures injured**
Tendons	239	638	37.4%
Nerves	52	174	29.9%

Arteries	32	116	27.6%

In terms of percentage, tendons were the most commonly injured structure (lacerated and partial injury) while arteries were the least frequently injured structure.

3.3.3 Intra-operative findings of FDS and FDP

Figure 3.9 illustrates the intra-operative findings of FDP and FDS for the index, middle, ring and little fingers.

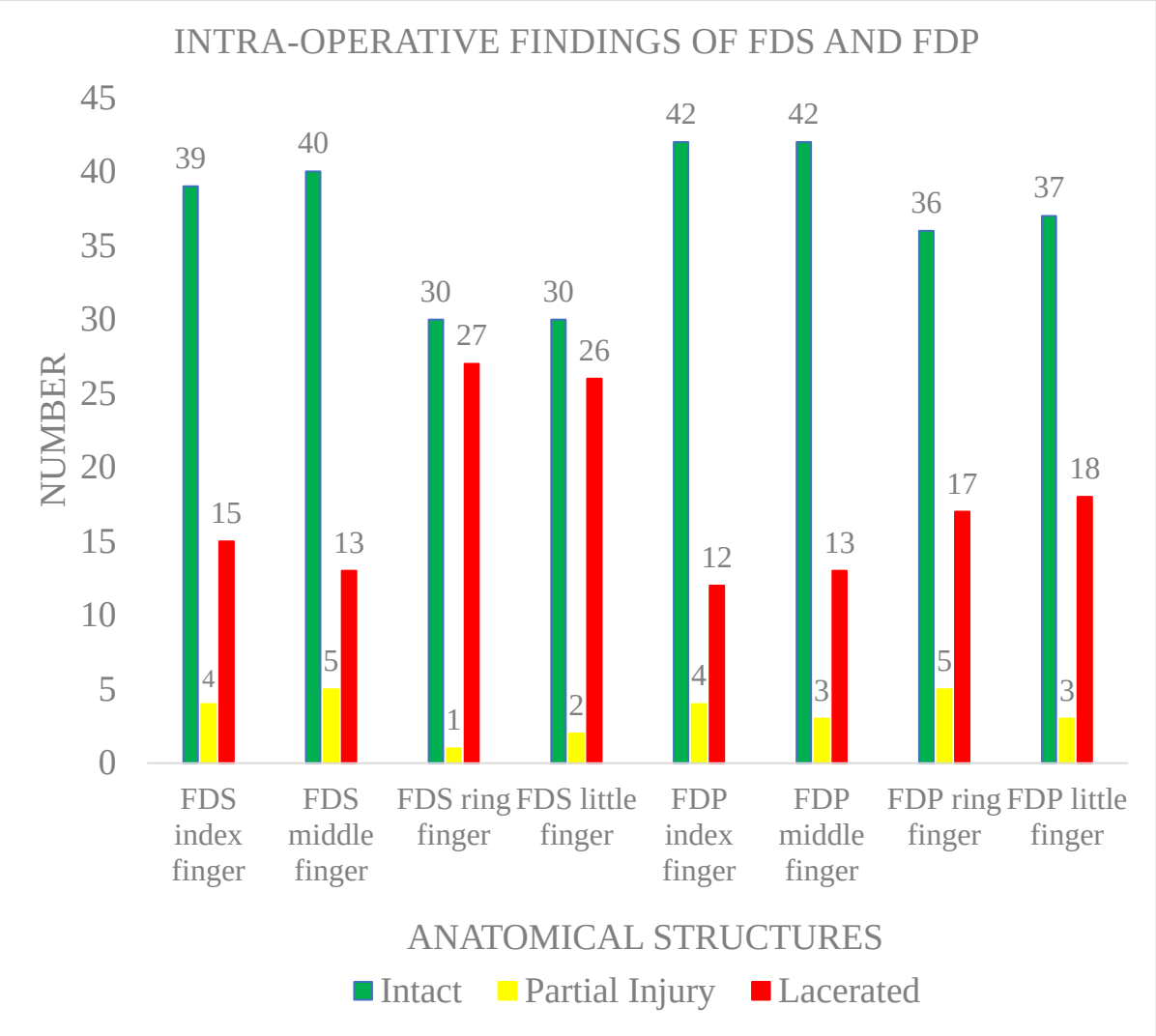

Figure 3.9: Intra-operative findings of FDS and FDP tendons.

There were more lacerated FDS tendons of index, ring and little fingers than lacerated FDP tendons for index, ring and little fingers respectively. The number of lacerated FDS and

FDP tendons of middle finger was the same. The ring and little fingers were more lacerated than middle and index fingers for both FDS and FDP groups.

3.3.4 Summary of intra-operative findings of FDS and FDP

Table 3.7 below illustrates the number of lacerated, partial injured and intact flexor digitorium superficialis (FDS) and flexor digitorium profundus (FDP) tendons (i.e. all the four FDS tendons and the four FDP tendons).

Table 3.7: Summary of the intra-operative findings of all FDS and FDP in the 58 injuries.

Anatomical structures	**Lacerated**	**Partial injury**	**Intact**	**Total number**
FDS	81	12	139	232
FDP	60	15	157	232

There were more lacerated FDS tendons than lacerated FDP tendons found intra-operatively. However the number of FDP partial injuries was more than FDS partial injuries.

3.3.5 Comparison of pre-operative and intra-operative findings

Table 3.8 below compares the pre-operative and intra-operative findings of the tendons, nerves and arteries (in terms of intact, partial injury and lacerated).

Table 3.8: Comparison of the pre-operative and intra-operative findings of tendons, nerve and arteries.

Anatomical structures	Pre-op Intact	Intra-op Intact	Pre-op Partial injury	Intra-op Partial injury	Pre-op Lacerated	Intra-op Lacerated
Tendons	425	399	33	40	180	199
Nerves	119	122	15	14	40	38
Arteries	97	84	1	1	18	31
Total	**641**	**605**	**49**	**55**	**238**	**268**

Comparatively, there were more anatomical structures that were found to be lacerated and partially injured intra-operatively than assessed pre-operatively to be lacerated and partially injured. Two hundred and sixty-eight (268) anatomical structures were found to be lacerated intra-operatively while 238 anatomical structures were assessed clinically to be lacerated. Similarly, 55 anatomical structures were partially torn intra-operatively while 49 anatomical structures were assessed clinically to be partially torn. However not all structures assessed to be lacerated and partially injured pre-operatively were even found to be so intra-operatively. Therefore in **section 3.4**, the intra-operative findings of lacerated, partially injured and intact tendons, nerves and arteries were analysed to assess the accurate and inaccurate diagnosis of the pre-operative clinical examination.

The intra-operative findings were analysed and classified and described below.

3.3.6 Spaghetti wrist

Twenty-eight out of the 58 zone V flexor injuries in this study could be classified as spaghetti wrist using the minimum definition as described by Kumar-Kempelingaiah et al. (25). This makes up 48.3% of the injuries. The number of structures injured in the spaghetti wrist ranged from three (one nerve, one artery and one tendon) to 14 (11 tendons, two nerves and one artery).

3.3.7 Ulnar triad injuries

Injuries to the ulna triad structures were found in 21 out of the 58 injuries operated. This means that concomitant injuries to the ulna triad structures were found in 36.2% of the injuries operated. Out of these, 18 cases (31.0%) were complete lacerations of FCU, ulna nerve and ulna artery and three of them (5.2%) were cases where two of the structures were completely lacerated and the other structure was partially lacerated or injured.

3.3.8 Simultaneous FCR and median nerve injuries

There were 14 cases where there was a concomitant FCR and median nerve injuries. That's simultaneous injuries to the FCR and median nerve was found in 24.1% of the injuries operated. This consisted of cases of either lacerated and/or partial injuries of FCR and median nerve.

3.3.9 Simultaneous ulnar and median nerves injuries

There were 10 cases of combined ulnar and median nerve injuries in the same wrist or forearm. This made up 17.2% of the injuries operated.

3.3.10 Simultaneous radial and ulnar arteries injuries

Among the patients included in the study, there was no patient who had a simultaneous injury to the radial and ulna arteries. However, there was one patient during the study period who had lacerations on both the radial and ulnar arteries but was rushed to theatre by the trauma and orthopaedic surgeons on call, consent could not be obtained and thorough clinical examination was not done prior to surgery. The patient was excluded from the study. It must be noted that 31 out of 58 injuries had complete laceration of either the radial or ulna artery.

3.4 ASSESSING THE ACCURACY OF PRE-OPERATIVE CLINICAL EXAMINATION

In this section, the results have been grouped into lacerated, partially injured and intact structures. The accuracy of pre-operative clinical examination findings of each of the 16

anatomical structures in all the injuries was analysed. The overall accuracy of the examination and also number of errors per examination are presented.

3.4.1 Accuracy and missed diagnosis of lacerated structures

Table 3.9 below demonstrate for each anatomical structure, the total number of lacerated structures (intra-operative), the number that was documented pre-operatively as lacerated (accurate diagnosis) and those that were not identified pre-operatively as lacerated (missed diagnosis) and expressed as a percentage.

Table 3.9: Frequency and percentage of accurate and missed diagnosis of each lacerated anatomical structure.

Anatomical structures	**Number of lacerated structures**	**Accurate Diagnosis**	**Missed Diagnosis**	**Percentage of Accurate Diagnosis**	**Percentage of Missed Diagnosis**
FCR	18	12	6	66.7%	33.3%
FCU	29	21	8	72.4	27.6%
FPL	11	9	2	81.2%	18.2%
FDS index finger	15	10	5	66.7%	33.3%
FDS middle finger	13	7	6	53.8%	46.2%
FDS ring finger	27	19	8	70.4%	29.6%
FDS little finger	26	18	8	69.2%	30.8%
FDP index finger	12	10	2	83.35	16.7%
FDP middle finger	13	9	4	69.2%	30.8%
FDP ring finger	17	14	3	82.3%	17.7%
FDP little finger	18	14	4	77.8%	22.2%

Superficial radial nerve	4	0	4	0.0%%	100.0%
Ulnar nerve	20	16	4	80.0%	20.0%
Median nerve	14	7	7	50.0%	50.0%
Radial artery	6	1	5	16.7%	83.3%
Ulnar artery	25	12	13	48.0%	52.0%%
Total	**268**	**179**	**89**	**66.8%**	**33.2%**

Among the tendon group, FDS to the middle finger had the highest rate of missed diagnosis of lacerated structures, followed by FCR and FDS to the index finger. FDP to the index finger had the lowest rate of missed diagnosis followed by FDP to the ring finger and FPL.

All the superficial radial nerve lacerations were missed pre-operatively. Half of all the median nerve lacerations were missed clinically. Ulna nerve had the lowest rate of missed diagnosis among the three nerves. Among the two arteries, radial artery had the higher rate (83.3%) of missed diagnosis but ulna artery also had a high rate (52%) of missed diagnosis.

3.4.2 Summary of the accuracy and missed diagnosis of lacerated structures

The accurate and missed diagnosis of the lacerated tendons, arteries and nerves were summated and illustrated in Table 3.10 below. The statistical significance of the difference between the number of lacerated structures and those that were accurately diagnosed pre-operatively was calculated and documented.

Table 3.10: Frequency and percentage of accurate and missed diagnosis of lacerated tendons, nerves and arteries.

Anatomical structures	**Number of lacerated structures**	**Accurate diagnosis *n* (%)**	**Missed diagnosis *n* (%)**	**95% CI**	**P-value**
Tendons	199	143 (71.9%)	56 (28.1%)	0.656-0.781	< **0.001**
Nerves	38	23 (60.5%)	15 (39.5%)	0.450-0.761	< **0.001**
Arteries	31	13 (41.9%)	18 (58.1%)	0.246-0.593	< **0.001**
Total	268	179 (66.8%)	89 (33.2%)	0.611-0.724	< **0.001**

The arteries had the highest rate of missed diagnosis of lacerated structures followed by the nerves. The difference between the number of lacerated structures (intra-operative) and accurate diagnosis (accurately diagnosed pre-operatively) was statistically significant for tendons, nerves and arteries.

3.4.3 Comparisons of the accuracy and missed diagnosis of lacerated FDP and FDS tendons

The accurate and missed diagnosis of the lacerated four FDS tendons and four FDP tendons were summated and illustrated in the Table 3.11 below.

Table 3.11: Frequency and percentage of the accurate and missed diagnosis of lacerated FDS and FDP tendons.

Anatomical Structures	**Number of Lacerated Structures**	**Accurate diagnosis**	**Missed diagnosis**	**Percentage of accurate diagnosis**	**Percentage of missed diagnosis**
FDS	81	54	27	66.7%	33.3%
FDP	60	47	13	78.3%	21.7%

Comparatively, there was a higher rate of missed diagnosis of lacerated FDS than lacerated FDP tendons.

3.4.4 Accurate and inaccurate diagnosis of partial injured structures

Table 3.12 below demonstrate for each anatomical structure, the total number of partially injured structures (intra-operative), the number that was documented pre-operatively as partially injured (accurate diagnosis) and those that were not identified pre-operatively as partially injured (inaccurate diagnosis) and expressed as a percentage

Table 3.12: Frequency and percentage of accurate and inaccurate diagnosis of each partially injured anatomical structure.

Anatomical structures	**Number of Partial Tears**	**Accurate Diagnosis**	**Inaccurate Diagnosis**	**Percentage of accurate diagnosis**	**Percentage of Inaccurate Diagnosis**
FCR	3	0	3	0.0%	100.0%
FCU	8	0	8	0.0%	100.0%
FPL	2	0	2	0.0%	100.0%
FDS index finger	4	0	4	0.0%	100.0%
FDS middle finger	5	0	5	0.0%	100.0%
FDS ring finger	1	0	1	0.0%	100.0%
FDS little finger	2	0	2	0.0%	100.0%
FDP index finger	4	0	4	0.0%	100.0%
FDP middle finger	3	1	2	33.3%	66.7%
FDP ring finger	5	0	5	0.0%	100.0%
FDP little finger	3	0	3	0.0%	100.0%
Superficial radial nerve	1	0	1	0.0%	100.0%
Ulnar nerve	7	2	5	28.6%	71.4%
Median nerve	6	2	4	33.3%	66.7%
Radial artery	0	0	0	0.0%	100.0%
Ulnar artery	1	0	1	0.0%	100.0%
Total	**55**	**5**	**50**	**9.1%**	**90.9%**

The only tendon whose partial injury was picked up clinically was FDP to the middle finger. Partial injury of two ulnar nerves and two median nerves were picked up clinically. The partial injury of all the other tendons, nerves and arteries were diagnosed inaccurately pre-operatively. The overall rate of inaccuracy of diagnosing partial injuries was very high (90.9%).

3.4.5 Summary of accurate and inaccurate diagnosis of partial injured structures

The accurate and inaccurate diagnosis of the partially injured tendons, nerves and arteries in the 58 examinations are summated and presented in Table 3.13.

Table 3.13: Frequency and percentage of accurate and inaccurate diagnosis of partially torn tendons, nerves and arteries.

Anatomical Structures	**Total Number of Partial Tears**	**Accurate Diagnosis**	**Inaccurate diagnosis**	**Percentage of accurate diagnosis**	**Percentage of inaccurate diagnosis**
Tendons	40	1	39	2.5%	97.5%
Nerves	14	4	10	28.6%	71.4%
Arteries	1	0	1	0.0%	100.0%
Total	**55**	**5**	**50**	**9.1%**	**90.9%**

Accurate diagnosis of partially injured nerves was higher than accurate diagnosis of partially injured tendon and arterial injuries. The values of the partial injured structures were too low to assess whether the difference between intra-operative and pre-operative findings was statistically significant or not.

3.4.6 Accuracy and over-diagnosis of intact structures

Table 3.14 below demonstrate for each anatomical structure, the total number of intact structures (intra-operative), the number that was documented pre-operatively as intact (accurate diagnosis) and those that were not identified pre-operatively as intact (over diagnosis) and expressed as a percentage.

Table 3.14: Frequency and percentage of accurate diagnosis and over-diagnosis of each intact anatomical structure.

Characteristics	**Number of intact structures**	**Accurate diagnosis**	**Over-diagnosis**	**Percentage of Accurate Diagnosis**	**Percentage of over-diagnosis**
FCR	37	34	3	91.9%	8.1%
FCU	21	17	4	81.0%	19.0%
FPL	45	43	2	95.6%	4.4%
FDS index finger	39	33	6	84.6%	15.4%
FDS middle finger	40	37	3	92.5%	7.5%
FDS ring finger	30	26	4	86.6%	13.3%
FDS little finger	30	24	6	80.0%	20.0%
FDP index finger	42	39	3	92.9%	7.1%
FDP middle finger	42	41	1	97.6%	2.4%
FDP ring finger	36	31	5	86.1%	13.9%
FDP little finger	37	33	4	89.2%	10.8%
Superficial radial nerve	53	47	6	88.7%	11.3%
Ulnar nerve	31	24	7	77.4%	22.6%
Median nerve	38	36	2	94.7%	5.3%
Radial artery	52	49	3	94.2%	5.8%
Ulnar artery	32	30	2	93.7%	6.3%
Total	**605**	**544**	**61**	**89.9%**	**10.1%**

Among the tendons, FDS to the little finger had the highest rate of over-diagnosis, followed by FCU and FDS to the index finger. FDP to the middle finger had the lowest rate of over-diagnosis.

Ulnar nerve had the highest rate of over-diagnosis among the three nerves followed by superficial radial nerve. Median nerve had the lowest rate of over-diagnosis.
The over-diagnosis of radial artery and ulna artery were similar.

3.4.7 Summary of accuracy and over-diagnosis of intact structures

The accurate and inaccurate diagnosis of the intact tendons, arteries and nerves in the 58 examinations are summated and presented in Table 3.15 below. The statistical significance of the difference between the number of intact structures and those that were accurately diagnosed pre-operatively was calculated and documented.

Table 3.15: Frequency and percentage of accurate diagnosis and over-diagnosis of intact tendons, nerves and arteries.

Anatomical structures	**Number of intact structures**	**Accurate diagnosis *n* (%)**	**Over-diagnosis *n* (%)**	**95% CI**	**P-value**
Tendons	399	358 (89.7%)	41 (10.3%)	0.867-0.927	< **0.001**
Nerves	122	107 (87.7%)	15 (12.3%)	0.819-0.935	< **0.001**
Arteries	84	79 (94.0%)	5 (6.0%)	0.890-0.991	< 0.686
Total	605	544 (89.9%)	61 (10.1%)	0.875-0.923	< **0.001**

The rate of over-diagnosis of intact structures was generally low but the arteries had the lowest rate. The nerves had the highest rate of over-diagnosis. The differences between the number of intact structures (intra-operative) and accurate diagnosis (accurate pre-operative findings) of intact tendons, nerves and total intact anatomical structures were statistically significant. However the difference between pre-operative and intra-operative findings of intact arteries was not statistically significant.

3.4.8 Accuracy and over-diagnosis of intact FDS and FDP tendons

The accurate and inaccurate diagnosis of the intact four FDS tendons and four FDP tendons in the 58 examinations are summated and presented in Table 3.16.

Table 3.16: Frequency and percentage of accurate diagnosis and over-diagnosis of FDS and FDP tendons.

Anatomical structures	Number of intact structures	Accurate diagnosis	Over-diagnosis	Percentage of accurate diagnosis	Percentage of over-diagnosis
FDS	139	120	19	86.3%	13.7%
FDP	157	144	13	91.7%	8.3%

The rate of over-diagnosis of intact FDS tendons was higher than over-diagnosis of intact FDP tendons.

3.4.9 Accurate and inaccurate pre-operative clinical diagnosis of each anatomical structure

Table 3.17 below illustrates the accuracy of the pre-operative clinical examination of the anatomical structures in each of the 58 injuries. For each anatomical, if the pre-operative finding was the same as the definite intra-operative finding, it was regarded as accurate diagnosis. If the pre-operative finding was different from the definite intra-operative finding, it was regarded as inaccurate diagnosis.

Table 3.17: Frequency and percentage of accurate and inaccurate diagnosis of each anatomical structure in the 58 injuries examined.

Anatomical structures	Total number	Accurate diagnosis	Inaccurate diagnosis	Percentage of accurate diagnosis	Percentage of inaccurate diagnosis
FCR	58	46	12	79.3%	20.7%
FCU	58	38	20	65.5%	34.5%
FPL	58	52	6	89.7%	10.3%
FDS index finger	58	43	15	74.1%	25.9%
FDS middle finger	58	44	14	75.9%	24.1%
FDS ring finger	58	45	13	77.6%	22.4%
FDS little finger	58	42	16	72.4%	27.6%
FDP index finger	58	49	9	84.5%	15.5%

FDP middle finger	58	45	13	77.6%	22.4%
FDP ring finger	58	45	13	77.6%	22.4%
FDP little finger	58	47	11	81.3%	18.7%
Superficial radial nerve	58	47	11	81.3%	18.7%
Ulnar nerve	58	42	16	72.4%	27.6%
Median nerve	58	45	13	77.6%	22.4%
Radial artery	58	50	8	86.2%	13.8%
Ulnar artery	58	42	16	72.4%	27.6%
Total	**928**	**722**	**206**	**77.8%**	**22.2%**

Among the 11 tendons assessed pre-operatively in the 58 injuries, FPL had the highest rate of accuracy of the clinical examination followed by FDP to the index finger and FDP to the little finger. FCU had the lowest accuracy of clinical assessment followed by FDS to the little finger and FDS to the index finger.

Among the three nerves, superficial radial nerve had the highest rate of accuracy of clinical examination followed by median nerve. Ulna nerve had the lowest rate of accuracy of pre-operative clinical examination. Radial artery had a higher rate of accuracy of clinical assessment than ulnar artery.

3.4.10 Summary of accuracy and inaccurate diagnosis of each anatomical structure

Table 3.18 below shows the number and percentage of accurate diagnosis and inaccurate diagnosis of tendons, nerves and arteries in the 58 injuries examined. The statistical difference between the total number of the various anatomical structures examined and the accurate pre-operative diagnosis was calculated and documented.

Table 3.18: Frequency and percentage of accurate and inaccurate diagnosis of tendons, nerves and arteries in the 58 injuries examined.

Anatomical structure	**Total number**	**Accurate diagnosis *n* (%)**	**Inaccurate diagnosis *n* (%)**	**95% CI**	**P-value**
Tendons	638	496 (77.7%)	142 (22.3%)	0.745-0.809	< **0.001**
Nerves	174	134 (77.0%)	40 (23.0%)	0.707-0.833	< **0.001**
Arteries	116	92 (79.3%)	24 (20.7%)	0.719-0.867	< **0.001**
Total	928	722 (77.8%)	206 (22.2%)	0.751-0.805	< **0.001**

The accuracy of clinical examination of tendons, nerve and arteries were similar. The differences between the intra-operative and pre-operative examination findings of all the tendons, nerves and arteries examined were statistically significant.

3.4.11 Accuracy of pre-operative clinical examination of FDS and FDP tendons

The accurate and inaccurate diagnosis of the four FDS tendons and four FDP tendons in the 58 examinations is presented in the Table 3.19 below.

Table 3.19: Frequency and percentage of accurate and inaccurate diagnosis of all FDS and FDP tendons in the 58 injuries examined.

Anatomical structure	**Total number**	**Accurate diagnosis**	**Inaccurate diagnosis**	**Percentage of accurate diagnosis**	**Percentage of inaccurate diagnosis**
FDS	232	174	58	75.0%	25.0%
FDP	232	186	46	80.2%	19.8%

The accuracy of the clinical examination of FDP was higher than FDP.

3.4.12 Accuracy of overall pre-operative clinical examination

The Table below illustrates the total number of examinations, accurate examinations, inaccurate examinations and their percentages.

Table 3.20: Frequency and percentage of accurate and inaccurate diagnosis in the 58 injuries examined.

Total number of examinations	928
Accurate diagnosis *n* (%)	722 (77.8%)
Inaccurate diagnosis *n* (%)	206 (22.2%)
95% CI	0.751 - 0.804
P-value	**< 0.001**

The rate of accuracy of clinical examination of the anatomical structures in zone V flexor injuries in this study was 77.8% whereas the rate of inaccurate examinations was 22.2%. The difference between the intra-operative and pre-operative findings of the anatomical structures examined was statistically significant.

3.4.13 Number of errors per clinical examination

In Table 3.21, the frequency of the total number of errors in each injury examined is tallied. There were 16 structures that were examined per each injury. The total number of injuries was 58.

Table 3.21: The frequency and percentage of each total number of errors in the 58 injuries examined.

Total number of errors per examination	**Number of injuries examined**	**Percentage of the number of errors**
0	5	8.6%
1	5	8.6%
2	8	13.8%
3	16	27.6%
4	5	8.6%
5	5	8.6%
6	7	12.1%
7	6	10.4%
8	1	1.7%

The number of errors per each examination in the 58 injuries ranged from zero to eight. The mean number of errors was 3.55. There were five out of 58 (8.6%) pre-operative clinical examinations that had no error. More than forty-one percent (41.4%) of the number of injuries examined had 4 or more errors.

CHAPTER 4

4 DISCUSSION

Under this chapter, the results and findings are analysed and explained in reference to other relevant studies and the functional anatomy of the zone V flexor region. The peculiar findings of the study are highlighted, and the implications of the overall study are discussed. The limitations of the study are described, and recommendations thereof.

4.1 DEMOGRAPHICS OF THE PATIENTS

The demographic characteristics of the patients who presented with zone V flexor injuries are discussed below.

4.1.1 Gender of patients

The findings from this study confirmed the fact that zone V flexor injuries occurs predominantly in males. The male to female ratio in this study was 4.1:1. This ratio is very similar to the findings of Gibson et al. which was 4:1 (19). The ratio was however higher than the findings of Raza et al. (2.4:1), Puckett et al. (3.6:1), Dehghani et al. (2.57:1), Chin et al. (2.2:1), Ashfaq et al. (3.9:1) and Kabak et al. (2:1) (15,16,26–28,30). The ratio was however lower than the findings of Kumar-Kempelingaiah et al. (4.8:1), Mafi et al. (12.9:1) and Yazdanshenas et al. (8.9:1) (11,25,29).

4.1.2 Age of patients

The mean age of the 56 patients was 32.2 years. This was slightly higher than the mean age documented in Raza et al.'s study (27 years), Gibson et al. study (27 years), Kabak et al.'s study (30.7 years), Dehghani et al.'s study (28.6 years), Kumar-Kempelingaiah et al.'s study (27.5 years), Chin et al.'s study (29 years), Ashfaq et al.'s study (27.1 years), Mafi et al.'s study (27.5) and Puckett et al.'s study (22 years) (15,16,19,25–30). The difference in the age could be due to the fact that this study enrolled only patients who were 18 years and older while most of the above-mentioned studies enrolled all patients (i.e. from day zero of life).

The study clearly indicates that zone V injuries occur predominantly among the youth; that is those below the age of 40 years. About 83.9% of the zone V flexor patients in this study were below the age of 40 years. This is similar to the findings of Puckett el al. and Kumar-Kempelingaiah et al. where 89% and 80% of the patients respectively were below the age of 40 years (25,28) .

4.1.3 Mechanism of injury

Assault or Homicide was the leading cause of zone V flexor injuries in this study (39.7%). This could be explained by the high crime rate in South Africa. Homicide rate in South Africa is six times the average rate in the world (39). The homicide rate is 38.4 per 100,000 population and this places South Africa as one of the highly ranked countries in terms of violence and crime (40). South African Police Service (SAPS) reported that 30.8% of the crime in South Africa are contact crime, of which 60% are common assault and grievous body harm assault (41). Almost all of the homicide or assault cases in this study were common assaults or grievous body harm assaults. Homicide rate is very common among the ages of 15 - 44 years (38) of which more than 84% of the patients in this study ages fall. The only study which shared a similarly high rate of assault was Kumar-Kempelingaiah et al.'s study (25) which was carried out in Trinidad where there is tolerance of violence (25). The tools used to assault the patients in this study were panga, broken bottle, knives and glass window.

Accidental injury was the second commonest mechanism of injury (32.8%). These injuries occurred when the patients were working in the house, were drunk and fell unto sharp objects, desperate attempt to open doors into their houses and also move out of their houses when it caught fire. The accidental injuries were caused by glass windows, broken bottle, knives and metal sinks. The causative agents of injury for the industrial injuries were grinder machine, gear box of a car, zinc roof, light bulb glass and scaffold spike.

Three patients inflicted the injury on themselves by punching glass windows while they were angry. This mechanism of injury is also described by Kabak et al. (27). In his study, 23.8% of the patients sustained the injuries through this mechanism while only 5.2% of the patients in this study injured themselves through this mechanism. Out of these three patients in this study, one admitted to having taken alcohol prior to sustaining the injury.

There were three parasuicide injuries in two patients. One of the patients sustained bilateral zone V flexor injuries. All the two patients were females. This is in contradiction to the study of Matzopoulos et al. (40) where the male to female ratio of suicide in South Africa was 5:1. These injuries were carried out with knife and razor blade.

4.1.4 Employment status of patients

From the study, it was noted that zone V flexor injuries occurs predominantly in people who were gainfully employed, studying or engaged in piece job. More than half (55.4%) of the patients were gainfully employed. This finding was in keeping with Jaquet et al.'s finding where almost half of the patients who sustained spaghetti wrist were employed when the injury occurred (2). The unemployment rate among the study population was 21.4%, but even with these patients, only two were on pension, a good number of them were seeking job to make ends meet.

4.1.5 Alcohol Intake

Thirty nine percent (39%) of the patients admitted that they had consumed alcohol when the injury occurred. This finding is comparable to the finding of Kabak et al. where 42.9% of the patients in their study had consumed alcohol when they sustained the injuries (27). Assault and accidental injuries were the main mechanisms of injury among patients who had consumed alcohol and sustained zone V flexor injuries.

Among the 23 patients who were assaulted in this study, 56.5% (13 patients) had consumed alcohol when the injury occurred. Among the 19 patients who sustained these injuries unintentionally (accidental injuries), 36.8% (7 patients) had consumed alcohol. This indicates that alcohol intake was significant among the patients whose mechanism of injury were assault (homicide) and accidental injuries.

4.1.6 Day of injury

Notably from this study, it was observed that zone V flexor injuries happened more often during the weekends especially, Saturdays and Sundays. Sixty three percent (63.7%) of the injuries occurred during the weekend (i.e. from Friday night to Sunday night). This is in

keeping with Schuurman et al.'s study where 66.7% and 60% of intentional and unintentional injuries in Cape Town, South Africa occurred during weekends (42).

4.1.7 Site of injury

Majority of the injuries (65.5%) occurred on the right upper limb. This was similar to the findings of Dehghani et al. (16), Ashfaq et al. (15), Mafi et al. (29), and Yazdanshenas et al. (11) but it is not in keeping with Raza et al. (30) and Kumar-Kempelingaiah et al.'s findings (25).

4.1.8 Dominant hand of patients

Ninety-eight percent (98.2%) of the patients enrolled in the study were right handed. This was slightly higher than the percentage of right-handed people as documented by Ashfaq et al. (95.5%) (15) and Ozinko et al. (89.7%) (1). Generally in the global population, there is a predominance of right-handed dominance which is between eighty-five and ninety percent (85-90%) (43).

4.1.9 Site of injury in relation to dominant hand of patients

Sixty percent (60.3%) of the injuries occurred on the dominant hand of the patient. This was higher than the findings of Kabak et al. where 52% of the injuries occurred on the dominant hand (27).

4.2 PRE-OPERATIVE CLINICAL EXAMINATION FINDINGS AND INTRA-OPERATIVE FINDINGS

There were fewer lacerated, and partially injured tendons and arteries documented on pre-operative clinical examination findings as compared to definitive intra-operative findings. But there were more lacerated and partially injured nerves picked up on pre-operative clinical examination than definitive intra-operative findings. However, not all these lacerated and partially injured anatomical structures that were picked up pre-operatively were found to be accurate in the definite intra-operative findings.

From the study, tendons were injured more commonly than nerves and arteries. In the zone V flexor region, the tendons are more superficial than the nerves and arteries. Furthermore, among the ulnar triad structures, FCU tendon was injured frequently than ulnar nerve and ulnar artery. This is also due to the more superficial location of the FCU tendon than the ulna nerve and artery making it more vulnerable to laceration. FDS tendons were also more injured than FDP tendons. This is also due to the more superficial location of FDS tendons in the zone V flexor region than FDP tendons. The FDS of ring and little fingers were frequently lacerated than FDS of index and middle fingers. Similarly, the FDP of ring and little fingers were also frequently lacerated than FDP of index and middle fingers. This is due to the ulna location of tendons of ring and little fingers in the wrist.

FCU was the most commonly lacerated tendon. This is in keeping with Chin et al.'s study where FCU was the most injured structure (26). This can be explained by its superficial and ulna location in the wrist. In cases of assault, the ulnar side of the forearm is used for protection hence more easily lacerated.

Ulnar nerve was frequently injured than median nerve and superficial radial nerve. A similar finding was documented in Vaughn's et al.'s study (44). This is due to its superficial location at wrist and its medial or ulna location. Ulna artery was more frequently injured than the radial artery. This is in agreement with Mafi et al.'s study (29)..

The commonest combined injury pattern observed in this study was laceration of FCU, ulnar nerve and ulnar artery (ulna triad). This is also on keeping with Chin et al.'s study (26), Yazdanshenas et al.'s study (11), and Vaughn et al.'s study (44) where injury to the ulna triad was the most common pattern. In our study, 31% of the patients had complete laceration of these anatomical structures which is exactly the same percentage that was reported in Noaman et al.'s findings (10). This was due to the proximity of these anatomical structures. At the wrist, these structures are very superficial and very vulnerable to assault and accidental injuries.

Another common pattern seen in these injuries was laceration of FCR and median nerve injuries. This was found in 24.1% of the injuries. Simultaneous ulna and median nerve injuries were also found in 17.2% of the injuries.

Quite a significant proportion of the injuries (48.3%) were spaghetti wrists. Spaghetti wrist are devastating injuries known to have significant impact on the quality of hand functioning (2,3). It is therefore expected that a good number of the patients in this study will have significant impairment of hand functioning, prolonged sick leave and reduced quality of life.

Arterial injury was quite common in the 58 zone V flexor injuries in this study. Either one of the two major arteries (radial and ulna arteries) was completely lacerated in 53.4% of the injuries examined. However, there was no single patient in this study who had both radial and ulnar artery completely lacerated. The rate of concomitant radial and ulna artery injuries (0%) was low as compared to Chin et al.'s findings (6.7%) and Noaman et al.'s findings (14%).

4.3 ACCURACY AND MISSED DIAGNOSIS OF LACERATED ANATOMICAL STRUCTURES

In general, the rate of missed diagnosis of lacerated tendons (28.1%) was lower than that of lacerated nerves (39.5%) and arteries (58.1%). Lacerated FDS tendon injuries were frequently missed more than FDP tendon injuries. Accurate diagnosis of FDS tendon injuries requires adequate knowledge about the functional anatomy of the FDS and FDP tendons and clinical examination skills. FDS flexes the proximal interphalangeal joint (PIPJ). The PIPJ is also flexed by FDP. In order to accurately examine FDS clinically, one need to eliminate the effect of FDP. The effect of the FDP can be eliminated by hyperextending the other unexamined fingers and then asking the patient to flex the examined finger. To be sure that the effect of FDP has been eliminated, the distal interphalangeal joint (DIPJ) of the examined finger should not be seen flexing during its examination. Among the FDS, the FDS to the index and middle fingers had the highest rate of missed diagnosis of lacerated structures.

The missed diagnosis of FCR and FCU was very high. This could be attributed to lack of knowledge of the proper clinical skills of these anatomical structures by the examining doctors. Both FCU and FCR are flexors of the wrist. In the presence of injury to either of these tendons, the intact FCU or FCR can flex the wrist though not with full strength. FCR needs to be examined by flexing the wrist against resistance to radial deviation. FCU needs to be examined by flexing the wrist against resistance to ulna deviation. If either of these

tendons is not thoroughly examined in this fashion, their isolated injuries will be missed on clinical examination.

In a striking manner, the rate of missed diagnosis of lacerated nerves was very high in general. All the superficial radial nerve injuries were missed, 50% and 20% of median nerve and ulna nerve injuries respectively were missed. This can be explained by the hypothesis put up by Lynch et al. (45) where a nerve impulse can jump a transected gap until 72 hours when Wallerian degeneration occurs. All the patients were examined within 24 hours of sustaining the injury.

The rate of missed diagnosis of lacerated arteries was also very high (58.1%). Radial artery was lacerated in six injuries and only one was diagnosed pre-operatively. This could be due to assessment of the arteries by only palpation and not performing Allen's test. It has been reported that when Allen's test is not carried out to assess arterial injury, the rate of missed diagnosis could be very high (17,19). This is because of good and rich backflow through the palmar arches (19).

The aforementioned factors and explanations accounted for the statistically significant difference between the intra-operative lacerated tendons, nerves and arteries and their corresponding pre-operative clinical examination findings. Surgeons should explore all structures in zone V flexor region and not be guided entirely by pre-operative clinical examination findings. This will avoid lacerated and partial injured anatomical structures not being repaired intra-operatively with consequent debilitating effects to the patient and possible litigations.

4.4 ACCUARCY AND INACCURATE DIAGNOSIS OF PARTIAL INJURED ANATOMICAL STRUCTURES

The rate of accurate diagnosis of the partially injured anatomical structures in this study was very low (9.1%). This low rate is expected because of residual function of the partially injured structures (36). In a study by Patel et al., none of the partially injured tendons was diagnosed clinically (18). In this study, partial injuries of two median nerves, two ulna nerves and an FDP tendon to the middle finger were diagnosed by clinical examination.

4.5 ACCURACY AND OVER-DIAGNOSIS OF INTACT ANATOMICAL STRUCTURES

The overall rate of over-diagnosis of the anatomical structures was low (10.1%). Among the anatomical structures, nerves had the highest rate of over-diagnosis. This could be attributed to the fact that nerves are very sensitive. When a nerve is contused even in the absence of laceration or a partial injury, the nerve has impaired sensation and motor function during the early hours and days. This can easily be diagnosed clinically as a laceration or partial injury. Ulna nerve had the highest rate of over-diagnosis among the three nerves. This is explained by the fact that ulnar nerve is more susceptible to injuries (including contusions) than median nerve and superficial radial nerve.

FDS to the little finger, FCU and FDS to the index finger had the highest rate of over-diagnosis among the tendons. FDS to the little finger has the least strength among all the FDS and FDP. So even in the presence of an intact FDS to the little finger, a clinician can easily assess it as a partial injury.

Gibson et al. explains that some clinicians are bias during their clinical examination of anatomical structures. This is due to their knowledge of the proximity of some anatomical structures and do not objectively assess each structure individually and on merit. For example, when examining, the ulnar triad structures, an examiner will mark FCU as lacerated without examining it when he or she finds the ulnar nerve injured. This will introduce observer bias and increase the rate of over-diagnosis. The high over-diagnosis rate of FCU can be attributed to this.

The arteries had a 6.0% rate of over-diagnosis. In the presence of swelling due to an injury, if the artery is examined clinically just by palpation, without a thorough Allen's test carried out, an intact artery will be assessed as lacerated artery pre-operatively. FDS had a higher rate of over-diagnosis than FDP. In general, clinical examination of FDP is much easier than FDP. Clinical examination of FDS requires more technique and understanding than FDS.

Patient factors such as pain, anxiety and lack of co-operation are also contributing factors to over-diagnosis of intact structures. The patient does not carry out the movement of the fingers and other instructions well. This will be interpreted by the examining doctor as a

malfunctioned (lacerated or partially injured) anatomical structure. Similarly, alcohol intake impairs the patient's apprehension of instruction and contributes to over diagnosis.

4.6 ACCURATE AND INACCURATE CLINICAL DIAGNOSIS OF ANATOMICAL STRUCTURES

The accuracy of examining tendons, nerves and arteries was fairly the same. It ranged from 77.7% to 79.3%. The difference in accuracy occurred when the anatomical structures were grouped into lacerated, partial injuries and intact structures. FPL had the highest rate of accuracy of clinical examination. This is because the clinical examination of FPL is comparatively easy. This is tested by flexing the distal phalanx of the thumb against resistance while stabilising the proximal phalanx. Hence, it is not surprising that its rate of accuracy is very high. Generally, the rate of accuracy of clinical examination of FDP tendons was higher than FDS tendon mainly due to the relatively high level of skills required in examination of FDS.

The high rate of inaccurate diagnosis of FCU is attributed to the high rate of over diagnosis, missed diagnosis and inaccurate diagnosis of its intact structures, lacerated structures and partially injured structures respectively (All of which have been explained above). It is worthy to note that FCU tendon, ulnar nerve and ulnar artery had the highest rate of inaccuracy of clinical examination among the tendon, nerve and artery groups respectively.

4.7 ACCURACY OF OVERALL PRE-OPERATIVE CLINICAL EXAMINATION

The accuracy of the entire pre-operative clinical examination of zone V flexor injuries in this study was 77.8%. The accuracy of clinically diagnosing lacerated, partially injured and intact structures was 66.8%, 9.1% and 89.9% respectively. The average of these is 55.3% but the high numbers of intact structures (605) as compared to lacerated structures (268) and partial injuries (55) increases the rate of accuracy of the clinical examination of the total anatomical structures to 77.8%. The rate of inaccurate diagnosis is 22.2%.

The difference between the definitive intra-operative findings and pre-operative clinical examination findings was statistically significant. Surgeons should therefore expect quite

different intra-operative findings than the documented pre-operative clinical examination findings.

4.8 NUMBER OF ERRORS PER CLINICAL EXAMINATION

The number of errors per each clinical examination ranged from zero to eight. About 41.4% of the 58 clinical examinations had four or more errors per each examination. Approximately nine percent (8.6%) of the examinations had no error on clinical examination. The number of errors per clinical examination of an injury is dependent on the nature of the injury; the examining doctor and the patient being examined.

4.9 FACTORS AFFECTING ACCURACY AND ERRORS OF PRE-OPERATIVE CLINICAL EXAMINATION

Factors affecting the accuracy of clinical examination have been clearly explained in sections 1.2.6 and 4.3.

4.10 HOW TO REDUCE ERRORS AND IMPROVE ACCURACY IN ZONE V FLEXOR INJURIES

The examining doctor needs to familiarise him or herself with knowledge of the origin, insertion, course and function of the tendons, nerves and arteries in zone V flexor region. The examining doctor needs to know how to clinically examine each tendon, nerve and artery in the zone V flexor region. Knowledge of the proximity of the anatomical structures should also be known. Each anatomical structure should be assessed individually and objectively no matter the pattern of injury, assumptions should not be made. Allen's test should always be used in assessing arterial injuries. The examining doctor needs to be thorough and meticulous in his or her examination.

The patient should be pain-free, calm and sober with a high level of co-operation. Patients who are drunk need to be re-examined when they are sober. Patients who are in pain needs to be given analgesia to reduce or minimise the pain. Patients who are anxious need to be re-assured and calmed down before clinical examination proceeds. The cause of a patient's poorer level of co-operation needs to be known and addressed. If it is language barrier, an interpreter needs to be engaged, if it's pain and anxiety, analgesia and counselling needs to

be done before a final documented clinical examination is carried out. In some instances, it may be necessary to examine the patients some few days after he or she sustains the injury to reduce the effect of the aforementioned factors.

It must however be stated that errors in clinical examination of all zone V flexor injuries are very difficult to reduce to zero. However, the error margin can be reduced in some injuries.

4.11 STUDY LIMITATION

The sample size of the study was small (58 injuries). The study was extended for another eight months to get this number.

4.12 RECOMMENDATION

We recommend further multi-centre studies (for large numbers) to assess the diagnostic accuracy of clinical examination of zone V flexor injuries.

CHAPTER 5

5 CONCLUSION

Zone V flexor injuries occur predominantly in males. It occurs mainly in young patients, especially those below the age of 40 years. The majority of these patients are employed, studying, engaged in a part time or contract job or seeking employment. There is therefore the need to ensure accurate pre-operative clinical assessment to enhance proper surgical planning and patient related outcomes.

Assault and accidental injuries are the leading causes of zone V flexor injuries in our setting. Majority of these injuries occur during the weekend. Alcohol is a significant contributory factor to zone V flexor injuries, especially patients whose mechanism of injuries are assault and accidental injuries. Majority of these injuries occur on the right hand and dominant side of the patients. Therefore, accurate clinical examination and surgical repair is essential to enhance the hand functioning and quality of life of the patients.

Spaghetti wrists were quite common in this zone V flexor injuries study with its attendant devastating effects on the quality of hand functioning and life in general. A complete laceration of ulna triad injuries was the commonest pattern of injury in these zone V flexor injuries. Simultaneous ulnar and median nerves were found in one-sixth of the patients. Simultaneous laceration of ulna and radial arteries was rare in our study population. However, lacerations of either of these two major arteries in zone V flexor injuries are quite common.

There was a high rate of inaccurate diagnosis of the anatomical structures. The error in assessing FDS tendon in zone V flexor injuries was higher than the FDP, partially due to clinical examination skills of the examining doctor. The inaccurate diagnosis of lacerated arteries was very high, partially due to Allen’s test not being carried out during examination of these injuries. The inaccurate diagnosis of lacerated nerves was high due to transmission across a transected gap and clinical examination skills. The accuracy of

diagnosing partially injured structures was very low due to residual function of the structures.

There was a statistically significant difference in the clinical examination of zone V flexor injuries in this study, especially examination of lacerated structures. There should therefore be a high index of suspicion to explore zone V flexor injuries in order to avoid missed injuries. Surgeons should expect to find more injuries intra-operatively than what was documented pre-operatively.

Clinicians should familiarise themselves with the functional anatomy of anatomical structures in zone V flexor region and learn the appropriate clinical skills in examining these structures especially FDS, FDP, FCR, FCU tendons and Allen's test. Patients also need to be examined under pain-free, less anxiety atmosphere with a high level of co-operation.

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APPENDIX

Appendix A: DATA COLLECTION SHEET (PART I) - DEMOGRAPHICS

ASSESSING THE PRE-OPERATIVE CLIINICAL EXAMINATION OF ZONE V FLEXOR INJURIES

Patient Number

Date and time that the patient is seen at CHBAH……..

Date and time of injury……..

Age of patient:…. Years

Sex of patient: Male ( ), Female ( )

Employment status: employed ( ) unemployed ( ) student ( ) Piece job ( )

Mechanism of Injury: assault or homicidal injury ( ), industrial injury ( ), accidental injury ( ) Suicide ( )

A brief summary of the mechanism of injury (with particular reference to the object causing the injury

……
……
……

Size of laceration: …… (cm)

Site of injury: Right ( ) Left ( )

Are you Right handed or left handed: Right ( ) Left ( )

Did you take alcohol before the injury occurred? Yes ( ) No ( )

Appendix B: DATA COLLECTION SHEET (PART II) - PRE-OPERATIVE CLINICAL EXAMINATION FINDINGS

ANATOMICAL STRUCTURE	INTACT	PARTIAL TEAR	LACERATION
FLEXOR CARPI RADIALIS			
FLEXOR CARPI ULNARIS			
FLEXOR POLLICIS LONGUS			
FDS TO INDEX FINGER			
FDS TO MIDDLE FINGER			
FDS TO RING FINGER			
FDS TO LITTLE FINGER			
FDP TO INDEX FINGER			
FDP TO MIDDLE FINGER			
FDP TO RING FINGER			
FDP TO LITTLE FINGER			
ABDUCTOR POLLICIS LONGUS			
SUPERFICIAL RADIAL NERVE			
ULNAR NERVE			
MEDIAN NERVE			
RADIAL ARTERY			
ULNAR ARTERY			

ABBREVIATION:

FDS: FLEXOR DIGITORIUM SUPERFICIALIS

FDP: FLEXOR DIGITORIUM PROFUNDUS

Appendix C: DATA COLLECTION SHEET (PART III) - INTRA-OPERATIVE FINDINGS

ANATOMICAL STRUCTURE	INTACT	PARTIAL TEAR	LACERATION
FLEXOR CARPI RADIALIS			
FLEXOR CARPI ULNARIS			
FLEXOR POLLICIS LONGUS			
FDS TO INDEX FINGER			
FDS TO MIDDLE FINGER			
FDS TO RING FINGER			
FDS TO LITTLE FINGER			
FDP TO INDEX FINGER			
FDP TO MIDDLE FINGER			
FDP TO RING FINGER			
FDP TO LITTLE FINGER			
ABDUCTOR POLLICIS LONGUS			
SUPERFICIAL RADIAL NERVE			
ULNAR NERVE			
MEDIAN NERVE			
RADIAL ARTERY			
ULNAR ARTERY			

ABBREVIATION:

FDS: FLEXOR DIGITORIUM SUPERFICIALIS

FDP: FLEXOR DIGITORIUM PROFUNDUS

Appendix D: HUMAN RESEARCH ETHICS CLEARANCE CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R14/49 Dr Emmanuel Dwomoh Osei et al

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M1711120

NAME: (Principal Investigator)	Dr Emmanuel Dwomoh Osei et al
DEPARTMENT:	Orthopaedic Surgery Chris Hani Baragwanath Academic Hospital - Hands Unit
PROJECT TITLE:	Diagnostic Accuracy of Pre-Operative Clinical Examination in Zone V flexor Injuries
DATE CONSIDERED:	24/11/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr M.C. Sathekga
APPROVED BY:	Professor CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	07/02/2018

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in November and will therefore be due in the month of November each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date 08/02/2018

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES