The application of imaging technologies in the detection of trace evidence in forensic medical investigation

By:

Jeannie Eileen Yana Cocks

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Abstract

Locard's Exchange Principle necessitates that the bodies of victims of crime be treated as secondary crime scenes. Imaging technologies should be implemented with a view towards discovering trace evidence that may aid subsequent investigations. In a country notorious for violent crime, it seems that South African medico-legal laboratories make minimal application of technology in the death investigation process and little attention is given to trace evidence. Non-destructive, non-invasive, portable and cost-effective tools are required. A torch, magnifying lamp, portable digital microscope and alternate light source were tested to gauge their potential for trace evidence detection on the bodies of victims of fatal interpersonal violence. Most studies apply these and similar tools to inert surfaces, with few focussing on their application to human skin. The most common evidence types discovered on the bodies and clothing of victims of fatal interpersonal violence, as well as the propensity of each tool to detect these, was evaluated in order to devise the best option for incorporation into the Pretoria Medico-Legal Laboratory routine. The study aimed to justify the investment of slightly more time, effort and funding into trace evidence recovery in the South African mortuary environment. It was also hoped that the application of these tools could be extended to the clinical forensic setting.

Opsomming

Strenggesproke, met verwysing na die sogenaamde uitruilbeginsel van Locard, behoort die liggame van misdaadslagoffers as sekondêre misdaadtonele beskou te word. Beeldingstegnologie behoort aangewend te word in die opspooring van sogenaamde spoorbewysstukke op te spoor wat verdere ondersoeke kan rugsteun. In ’n land berug vir geweldsmisdaad, blyk dit dat Suid-Afrikaanse regsgeneeskundige labratoriums baie min gebruik gemaak van tegnologie in die ondersoek van dood en min aandag word gegee aan die belang van spoorbewysstukke. Nie-indringende, nie-vernietigende en koste effektiewe apparate is hiervoor nodig. In hierdie studie is ’n flitslig, vergrootglas ondersoeklamp, draagbare digitale mikroskoop en alternatiewe ligbron getoets om hulle potensiaal in die opspooring van spoorbewysstukke op die liggame van slagoffers van dodelike interpersoonlike geweld vas te stel. Die meeste studies verwys na die gebruik van hierdie instrumente op onreaktiewe oppervlaktes, en slegs enkele artikels fokus op die gebruik daarvan op menslike vel. Die mees algemene tipes bewysmateriaal gevind op die liggame en kleding van slagoffers van dodelike interpersoonlike geweld, sowel as die geneigdheid van elke instrument om dit op te spoor, is geëvalueer om die beste gebruiksopsie te vind en vir insluiting in die operasionele roetine van die Pretoria Regsgeneeskundige Laboratorium. Die studie poog om die effe hoër koste, groter tydsbesteding en meer moeite om spoorbewysstukke in die Suid-Afrikaanse lykshuis opset te versamel, te regverdig. Daar word ook gehoop dat hierdie tegnieke in kliniese geregtelike geneeskunde aangewend sal kan word.

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Abbreviations

AFIS	Automated Fingerprint Identification System
ALS	Alternate Light Source
CODIS	Combined DNA Identification System
CSI	Crime Scene Investigation
CSVR	Centre for the Study of Violence and Reconciliation
CT	Computer Tomography
DFO	1,8-Diazafluoren-9-One
DNA	Deoxyribonucleic Acid
FBI	Federal Bureau of Investigation
FLS	Forensic Light Source
FPS	Forensic Pathology Services
GSPS	Genetic Sample Processing System
INTERPOL	International Police
IR	Infra-Red
LED	Light Emitting Diode
Lodox®	Low-Dosage X-Ray
MLL	Medico-Legal Laboratories
MRC	Medical Research Council
MRI	Magnetic Resonance Imaging
NIBIN	National Integrated Ballistic Information Network
nm	Nanometres
PCR	Polymerase Chain Reaction
PDQ	Paint Data Query
PMLL	Pretoria Medico-Legal Laboratory
PSA	Prostate Specific Antigen
PVA	Pedestrian-Vehicle Accident
SANE	Sexual Assault Nurse Examiners
SAPS	South African Police Service
UN	United Nations
UV	Ultra Violet
WHO	World Health Organization

Chapter 1: Introduction

It was hypothesized that the routine use of newer technological aids would facilitate evidence recovery from the bodies of homicide victims. In addition, such technology was considered to be accessible and could be implemented as part of a protocol in Medico-Legal Laboratories (MLL) to enhance the administration of justice in South Africa. This study aimed to establish the viability and value of applying new technologies to the examination of dead bodies prior to autopsy in order to aid trace evidence recovery.

It was envisaged that this study would (1) either recommend or oppose the applicability of new technologies and justify the use of additional time, funds and effort in the recovery of trace evidence from the bodies of victims of interpersonal violence, and (2) determine if the investigation and investment of new technologies and techniques would be of use and subsequently aid the administration of justice.

Several questions were devised to gauge the situation. These were: (a) would the routine application of relatively simple technologies to the examination of victims of contact interpersonal violence improve trace evidence detection, (b) which technological advancements would prove to be viable and valuable for implementation into our mortuary routine, and (c) does the recovery of trace evidence from dead bodies facilitate and enhance the investigation into the circumstances of death of victims of interpersonal violence in our country?

This was a prospective study conducted to analyse the value of investing in new technologies for use in our local death investigations. Emphasis was placed on the types of trace evidence detected on the bodies and clothes of victims of interpersonal violence, and the subsequent usefulness of this evidence to the investigation of these deaths. It was hoped that this study would serve to enlighten the South African scientific community as to the value and viability of aspiring to international standards for the medico-legal investigation of death.

It was also envisioned that this thorough approach to body examination would potentiate a similar approach in the realm of clinical forensic medical examination. This has the potential to greatly aid the investigation of crime as hospitals deal with all the non-fatal cases of interpersonal violence; a number which is believed to greatly exceed our own case load.

1.1 Literature Review

1.1.1 Background

The culture of this millennium is one of constant improvement and re-invention. Individuals from all fields are channelling their energies towards improving their disciplines, particularly through the development of new technologies and techniques. Efforts are aimed at reducing cost, time and effort expenditure; in favour of increasing output, quality, safety and efficiency.

The same applies to the field of forensics, with the recovery of evidence being a prime concern. The idea that evidence found at a crime scene can create links to individuals involved and offer clues as to the reconstruction of events is encapsulated by Locard's Exchange Principle: "Every contact leaves a trace".[1]

In 1910 Edmund Locard (1877-1966) recognized the value of trace or contact evidence in the forensic world. Locard's famous mantra forms the cornerstone of modern forensic investigation. The principle is based on the idea that when any two items come into contact there will necessarily be an exchange between them and a trace of each will be deposited onto the opposite surface. This extends to criminal scenarios where there is always a transfer of evidence between the perpetrator and the scene or the perpetrator and the victim. Evidence of a perpetrator's presence can never be wholly absent from the scene of crime or the clothing or body of the victim. An individual will not only leave traces of their presence in a location, but will also take traces of the location away with them, creating a link.

Eloquently put by P.L. Kirk (1953)[2]:

> 'Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as a silent witness against him. Not only his fingerprints or his footprints,

> but his hair, the fibres from his clothes, the glass he breaks, the tool mark he leaves, the paint he scratches, the blood or semen he deposits or collects. All of these and more bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is factual evidence. Physical evidence cannot be wrong, it cannot perjure itself, it cannot be wholly absent. Only human failure to find it, study and understand it, can diminish its value.'

These traces need only be looked for in order to be found and play their role in the investigation.

As stated above, this transfer of evidence is not limited to inanimate objects, but can be deposited on the body of a victim of crime via the same mechanism. This would suggest that the victim's body should be treated with the same care, diligence and vigilance as the physical crime scene; and trace evidence should be meticulously sought for in the same manner. A secondary crime scene is any location subsequent to or other than the original location where the crime took place where additional evidence may be found.[3] In this way, the victim's body can be considered a secondary crime scene.

1.1.1.1 Global Situation

Homicide is responsible for over 500 000 deaths per year worldwide.[4] Violence was declared a leading global health problem by the World Health Assembly in 1996.[5]

1.1.1.2 South African Crime

South Africa has earned notoriety as one of the crime capitals of the world.[6] We live in a country where crime and interpersonal violence is common. According to the Medical Research Council (MRC), 89 murders are committed each day on average in South Africa.[6] Homicide is the leading contributor to the injury burden placed on the public health system.[7] In the period of 2008-2009, approximately 2.1 million serious cases of crime were registered in South Africa with 18148 of these cases being homicides.[8] Four of our major cities have been ranked in a study listing the 50 Most Violent Cities in the World.[9] Pretoria is the capital city of our country, but it is neither the largest nor most violent city in South Africa. In support of this, Pretoria is not even ranked within the above-mentioned study's listing.[9]

In 2004 the South African government set a goal to reduce the occurrence of contact crimes (crimes against the person) by 7-10% per annum after comparing unfavourably with other INTERPOL-member countries.[8] Although our country's culture of political strife has been quelled somewhat, the levels of interpersonal violence persist to be unacceptably high.[10]

South Africa ranks second in the world for murder, and first for assaults and rape per capita.[11] The phenomenon of rape-homicide is reported to be more common in South Africa than all forms of female homicide in the United States.[12] Estimates of rape on an annual basis in South Africa are in the region of 500 000.[11] Young South African male homicide rates are nine times the global rate, and female homicide in our country is almost as excessive.[10]

According to the United Nations (UN), 270 000 pedestrians are involved in accidents and lose their lives on the roads each year.[13] The WHO reports that pedestrian casualties account for 22% of the total 1.24 million road traffic deaths.[14] More than 5 000 pedestrians are killed on the world's roads each week.[15]

1.1.1.3 South African Demographics

South Africa has a population of 51 770 560, with its smallest province, Gauteng, hosting the largest population (12 272 263 people).[16] The Gauteng population is comprised of 77.4% Black Africans, 15.6% Whites, 3.5% Coloureds, 2.9% Indians/Asians and 0.7% other races[a].[16] There are 49.6% females,[16] resulting in a male-to-female ratio of approximately 1:1. South Africa as a whole has similar distributions of race and gender,

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[a] It is recognized that the terms 'Black', 'White', 'Coloured', 'Indian' and 'Asian' have no scientific basis and are merely social classifications of various population groups.

with almost 8 in 10 people being Black Africans.[16] Black Africans constitute the largest group in all the provinces except the Western Cape where Coloureds predominate.[16]

The highest rate of crime per capita is in Gauteng, according to reports by the South African Police Service (SAPS).[17] This study was conducted at the Pretoria Medico-Legal Laboratory (PMLL), situated in the Gauteng province, which admits the majority of cases from Pretoria, except for a small portion which is handled at two other medico-legal facilities. The population of Pretoria is estimated to be 2 141 717.[18]

Homicides comprise approximately 20% of total admissions to the PMLL.[19] This refers to any case admitted and treated as a homicide and includes blunt-force trauma, sharp-force trauma, manual and ligature strangulations, and gunshot related deaths.

A pedestrian-vehicle hit-and-run incident can also be considered a contact crime where evidence is transferred between the assailant (vehicle) and the victim. There are more than 270 000 pedestrian fatalities each year in the world.[20] Between 37 and 45% of all road-collision fatalities in South Africa are pedestrians,[21] which means that approximately 4500 pedestrians are killed each year in South Africa.[22] Comparing the cities of Cape Town, Durban, Johannesburg and Pretoria, Pretoria had the fewest number of pedestrian deaths, but this was shown to be on the increase.[23]

1.1.1.4 Current Practice

Internationally, the field of forensics is constantly evolving with new machines and technologies and large inter-connected databases greatly furthering investigative crime-solving efforts. International journal articles boast new methods or devices designed to improve the investigation of crime. Evidence recovery, analysis and storage are the focus of improvement initiatives. South Africa has been left behind. The reality is that our approach to crime solving is not evolving at the same rate that crimes are being committed.

One reason for this stagnation may be that, as a developing country, South Africa’s resources are limited. Consequently, it may be felt that our money is better invested in delivering basic services and fulfilling primal needs in order to improve the standard of living of our nation; rather than indulging in the latest crime-fighting technologies. Excessive violence means a huge case load needing to undergo medico-legal investigation in our country, with time and resources having to be spread thin in order to accommodate the body count.

In general, the autopsy in the mortuary has remained a fairly standard procedure for decades. In well-resourced countries, the use of technology such as CT (computer tomography) scans, MRIs (magnetic resonance imaging) and stereomicroscopes – among other technologies – to conduct modern forensic medical death investigation has become more prominent and almost an expectation. It does not appear that the application of technological advances is given the same amount of attention in South African morgues. Currently, only the MLLs of Tygerberg and Salt River in South Africa make use of technology such as Lodox® scans for quick full-body X-rays. This is not available at other South African MLLs which could imply that the same priority is not given to the application of technology in the death investigation process. Real-time application of technology could include the modalities explored in this study, as well as many others of which most are not even aware. A case could be made that the additional expense and effort of exploring and implementing more thorough evidence recovery protocols is exorbitant, but if the bigger picture is taken into account, it will become evident that role players and investigators are not prioritizing important concerns. It can be argued that the application of these and other technologies could go towards aiding the battle against crime.

It has been purported that the SAPS do not operate at levels of optimal efficacy and that crime scenes and investigations could be better managed.[24] Members in the Criminal Justice Policy Unit at the Centre for the Study of Violence and Reconciliation (CSVR) have stated that police sometimes fail at even basic routine police work, such as carrying out thorough investigations; serving to reinforce the perception that police efforts are less than satisfactory.[25] A victimisation survey that was conducted found that victims of crime are particularly dissatisfied with police performance.[25] Some even go so far as to call the South African police and justice system 'incompetent'.[24]

One of the measures proffered to combat the high rates of violence and crime in our country is the improvement and reinforcement of evidence-based crime investigation procedures.[26] Investigations need to be better managed and supervised.[26]

The media is quick to report when crime scenes are not managed optimally for the discovery and retention of crucial evidence.[24] To demonstrate this, the poor police performance in the recent Oscar Pistorius case was mentioned in global media:

> 'The incident has embarrassed the South African police who regularly come under fire for failing to reduce one of the highest crimes rates in the world and dispel perceptions of a force that is poorly trained.'[27]

Previously, the administration of MLLs was under the management of the SAPS, but this changed in approximately 2006 to fall under the jurisdiction of the Department of Health. The SAPS and the Forensic Pathology Services (FPS) now view themselves as separate entities, which may have created rifts in communication and a tendency to work in isolation. It can always be argued that both divisions struggle with issues of under-funding and resource limitation. To address this, the 2013 Budget Speech aimed to reassure the country that funds are being reprioritized to 'improve detective, investigative and forensic capabilities'.[28]

The outlook is not wholly bleak; a new state-of-the-art forensic laboratory with cutting-edge technology was opened in July of 2012 in the Western Province.[29] This promises to address the excessive case load as well as increase efficiency of case processing.[29]

Burton (2007)[30] considers the initial external examination of victims' bodies to be neglected and poorly documented. Beyond checking the pockets of the clothing and performing the autopsy, the victim's body is not routinely searched for trace evidence in South African mortuaries.[30] Exceptions may be suspected rape-homicides, high profile and media-related cases which are often subjected to intense scrutiny. These cases cause public outcry and investigators must be seen to be making every effort to solve them. Ideally, this attitude and approach should be applied to all deaths; provided that staffing, time and money allow.

1.1.2 Databases

One area which plays a role in determining the usefulness of evidence and sets countries such as the United States of America apart from South Africa is the implementation of local and national databases. These include CODIS (Combined DNA Identification System) for logging DNA profiles, AFIS (Automated Fingerprint Identification System) for cataloguing and matching fingerprints, NIBIN (National Integrated Ballistic Information Network) for identifying recovered cartridges, PDQ (Paint Data Query) for car paint chips, and Operation Bigfoot for shoe marks; to name a few. These databases allow investigators to perform blind searches in the hopes of matching evidence with possible sources or the profiles of previous offenders. South Africa has some of these databases in place (such as AFIS), but they are not yet on the scale that they need to be in order to have their potential realised.

CODIS is maintained by the FBI.[31] A 2008 Interpol survey found that 54 countries employ DNA databases.[32] This is a 350% increase since 1999.[32] In 2012, Brazil became the 56th country to pass DNA database legislation.[29] DNA extracted from biological evidence found at crime scenes is used to create a genetic profile which is then entered into the DNA database and used to search for matches with previous offenders and link serial cases.[33] Biological evidence is used to recognise serial offenders when multiple hits turn up on the DNA database.[33] It is also used in the Innocence Project[34] to exonerate falsely accused inmates who were previously convicted without the use of DNA evidence. Switzerland is another country making use of a DNA database.[35] In total, 398 DNA profiles of the 1739 stains processed in a study by Castella and Mangin (2008)[35] were able to be sent to the Swiss national DNA database and subsequently identified 136 persons.

In August 2012, Mauritius received the CODIS software from the FBI for implementation of their own DNA database.[29] Mauritius's crime rates are nowhere in the magnitude of that of South Africa yet a small country such as this realised the benefit of this freely available technology.[29]

In these countries, there need not be a suspect with which the evidence can be compared. The implementation of a full DNA database in South Africa was recently a topic of much debate. Little known to the public, South Africa actually has a DNA database, but current legislation limits its size and subsequent capacity to aid investigations.[29] Our database is still in its infancy and the need and potential of a fully established DNA database is only beginning to dawn.[29] The fact is, the larger the database – that is, the more DNA profiles it contains – the better the chance of finding a "hit" or match during an investigation.[29]

Even with a DNA database, however; South Africa still lacks other evidence type databases. Without comparison samples available, such as the car that supposedly hit a pedestrian, evidence such as paint chips recovered from a victim's body are of little use. Its value in court proceedings becomes greatly diminished when evidence can only offer vague indications of origin.

A scathing opinion-based review of the forensic situation in South Africa by Chris Asplen[11] stated that a country can have the best training and equipment in the world, but the progress of crime-solving is stunted by the limitations of the legislation in existence at the time. Despite having world-firsts in DNA analysis robotics, its true potential was not exploited as South Africa lacks the legislation to implement a full national DNA database. The technology to which he refers (the Genetic Sample Processing System or GSPS) has since been decommissioned and will be dismantled soon.

The South African government is currently reviewing a new Bill called the Criminal Law (Forensic Procedures) Amendment Bill [B2-2009].[29,36,163] When passed, this bill will ensure that every individual arrested and/or convicted for an offence will have a sample of their DNA collected, analysed and loaded onto the national database.[29]

There are no official statistics for the recidivism rate in South Africa, but estimates range from 55% to 99%.[37] This suggests that South Africa has a high rate of repeat offenders, and the recidivistic nature of many crimes[29] means that it would be only a matter of time before a profile loaded from a current crime scene will match to an individual previously arrested or convicted and thus create new leads in an investigation. President Jacob Zuma granted a pardon to 37 783 prisoners in the spirit of Freedom Day (27 April 2012).[38] Forty-seven of these criminals had re-offended within a month of their release for offences as severe as murder and rape.[38] Considering the rate of crime in our country, this time-saving quality alone recommends the implementation of a national DNA database.

Even if an individual has not been previously convicted or arrested, there is still the possibility of linking crimes together with matching unknown profiles in order to increase the chances of finding a suspect.[29] The use of a DNA database can quickly rule out or pinpoint suspects which can save the already valuable and scarce time and effort of investigators to rather be focused elsewhere.[29] The crimes committed by repeat-offenders tend to increase in severity over time, making the quick identification of suspects imperative.[29]

Machado *et al.* (2011)[39] (Portugal), Stackhouse *et al.* (2010)[40] (Wales), and Prainsack and Kitzberger (2009)[41] (Austria) conducted studies where individuals who had their DNA profile on a database were interviewed. The conclusion of these studies was that the individuals felt that their DNA should be on the database and should even be retained if they were found innocent. These studies could aid in voiding the arguments around human rights issues – specifically the right to privacy as stated in the Bill of Rights[42] – that currently impede the implementation of databases. The implementation of databases is in the interest of the greater good.

1.1.3 Prosecution and Conviction Rates

Despite the increasing crime rate in South Africa, conviction rates have decreased over the years; with the most severe crimes of murder and rape having the lowest conviction rates (South Africa).[25] Prosecution rates are also on the decrease, with prosecutors choosing to pursue only cases which have a high likelihood of conviction.[43] Approximately only 11% of all reported crimes are prosecuted in South Africa.[43] Perpetrators of serious violent crimes have less than a 1 in 50 chance of being caught and punished.[43] This is partly because cases without sufficient evidence to prove guilt beyond a reasonable doubt are abandoned.[43]

If we as forensic medical investigators can offer any form of additional corroborative evidence to increase the likelihood of prosecution and subsequent conviction, then definite efforts need to be made towards this goal. In fact, it is the responsibility of all institutions to make an effort towards increasing this success rate.

Incidents of sexual assault are on the increase.[44] This flags this form of violence as needing particular attention from all parties involved in order to thoroughly investigate these cases.[45] According to practitioners at the Hennepin County Medical Centre (United States of America), the collection of evidence from these victims correlates to maximizing the successful prosecution of the guilty party.[45] In several studies[45-49] conducted in the United States of America, conviction rates for sexual assault ranged from 8-20%.

Rape victims are unlikely to report the crime against them (United States of America),[50] and when they do, it is unlikely that they see their rapist convicted of the crime. In South Africa, it is estimated that only every 1 in 20 cases of rape is reported to the police.[51] Only 37% of women, who reported their victimization to police, saw their case referred for criminal prosecution.[52] Less than half of these cases resulted in a conviction.[52] Factors which influence a prosecutor's decision to prosecute a rape case are the presence of injuries, whether a weapon was used, the level of fear experienced by the victim, whether the victim had previously been raped by the rapist and whether a restraining order against the rapist was already in place (United States of America).[53]

1.1.4 Trace Evidence

Trace evidence refers to evidence that is present in often microscopic, but measurable amounts and includes strands of hair, chips of paint, individual fibres, shards of glass etc.[54] It is generally difficult to detect these traces with the naked eye alone.

There is virtually no limit to the traces that could be found on a victim's body, albeit each with varying degrees of uniqueness and subsequent usefulness to the investigation. Blood, seminal fluid, saliva, cosmetics, foreign fibres and hairs, glass fragments, vegetation and debris – to name a few – are all possible clues that can be recovered from the bodies of victims of interpersonal violence. This evidence can prove that a suspect came in contact with the victim around the time of the crime, and can subsequently serve to incriminate or exonerate the individual.[55]

Trace evidence offers two fundamental issues in its detection: firstly, the evidence is often minute and present in such a finite amount that the likelihood of noticing it with the naked eye is very low; and secondly, the evidence (e.g. fluids or latent fingerprints) often has a low contrast to the background it is deposited on, making its detection highly improbable to near-impossible.[56]

Dusting methods, as well as the use of magnification and lighting all help to combat these issues. Fluorescence is perhaps the most powerful parameter which can enhance the likelihood of trace evidence detection as all organic-based specimens fluoresce to some extent.[56]

Evidence promising DNA matching to an individual is often considered the most valuable, but this also depends on the resources of the country and whether or not there is a suspect. Most fatal violent altercations between an assailant and victim will involve anything from grabbing, slapping and punching to hair pulling, throttling and biting. This means that skin cells, hair, fibres and bodily fluids can be transferred from one to the other. Bruises and bite marks may leave identifiable patterns, and bites may have recoverable saliva present. Sexual assaults are particularly likely to involve transfers of bodily fluids, including blood, saliva, vaginal secretions and seminal fluid.

1.1.4.1 Semen

Many forensic cases address issues of sexual assault[57] and much scientific literature follows this theme, with a focus on discovering seminal fluid. Sexual Assault Nurse Examiners (SANE), or forensic nurses, primarily search for blood and semen as sources of foreign DNA on sexual assault victims and their clothing.[33] Foreign hairs are also of value.[33] Semen has a broad excitation spectrum, so multiple wavelengths can be exploited in order to illuminate this substance when using an Alternate Light Source (ALS).[57]

Several improvements and refinements have been made to the clinical sexual assault evaluation protocol over the years, but deficits still exist. It seems that agreements cannot be made as to the optimum evidence collection techniques or equipment to use, the persistence of the evidence and what interpretations can realistically be made from the evidence found.[58] There is no research pinpointing the best method for collecting all the possible types of evidence.[58] Data is also limited as to how long the deposited materials can be expected to survive on the body of victims and suspects.[58] Studies suggest that the majority of cellular material – that is, containing DNA for further analysis – is lost or degraded after 2-3 days.[59-60] One study found that spermatozoa should be recoverable from the vagina for the first 24 hours and sometimes even up to 6 days after ejaculation.[61] Evidence collected from the bodies of child victims of sexual assault is unlikely to yield positive results for semen if the examination takes place over 24 hours after the assault.[62] Examination of unwashed clothing and linens should be vigorously pursued because fluids such as semen and blood can be longer retained on clothing than on the victim's skin.[62]

The lack of positive seminal fluid findings during an examination does not mean that recent sexual intercourse did not occur, as studies have shown that 34% of rapists are sexually dysfunctional and 40% wear condoms.[63-64] Another study found that that only 1% of oral rape cases were positive for the presence of sperm, with 2% for rectal rape, 19% for cases with skin contact and 37% of cases with vaginal involvement.[63] The acid phosphatase test performed better than other tests in all instances, but still did not reach detection levels near 100%.[63]

It may seem that the odds are not in the investigator's favour, but the presence of this evidence is confirmatory of a recent sexual encounter. This means that although samples are not found as often as hoped for, the few that are found have the potential to contribute to the subsequent investigations.

1.1.4.2 Saliva

Saliva found at crime scenes can be due to biting, sexually-related acts, or expectoration.[65] Saliva is similar to semen in that it does not have any readily visible constituent.[65] At present, the only fairly reliable means of testing for saliva is to test for amylase activity[65] even though amylase is also present in other body fluids such as urine.

1.1.4.3 Other Evidence

Other evidence types receive far less attention than biological fluids, but also bear the potential to contribute significantly to an investigation.

1.1.4.3.1 Geological Samples

Soil or other geological samples found on the shoes of a suspect or victim,[66-67] or on the tyres of a vehicle can be linked to an area where that soil composition is likely or is known to occur. This is often useful in raising a red flag that a body may have been moved if soil particulates found on the body do not match that of where the body was found.[67]

1.1.4.3.2 Botanical Samples

Similar to geological samples, botanical samples recovered from the body of a victim or suspect can also indicate areas where the individual concerned has been previously.[68] Pollen and other trace botanical samples are also commonly found on the skin and hair of individuals.[69]

1.1.4.3.3 Hair

If recovered hairs are found to have the roots still attached, DNA can be retrieved and analyzed.[70] If no root is present, it is still possible to at least make exclusions with regards to the colour and texture.[71] Hair can also be used to show drug use. The way in which a hair is broken can indicate if it was removed violently or shed naturally.[71]

1.1.4.3.4 Fibres

Fibres can be categorized according to their composition (e.g. polyester, cotton etc.) and colour, and may then be linked to a certain fabric type, manufacturer, and possibly a certain batch of clothing, fabric or carpets.[72]

1.1.4.3.5 Entomology

The application of entomology, or the study of insects and their life cycles, to forensic investigations has found increased popularity in recent years. Insect life and their eggs and larvae collected at a scene or from a victim's body can help an entomologist to give a reasonably accurate determination of the post mortem interval.[73-74] Insects have also been known to ingest toxins from dead bodies and toxicological analysis may reveal drugs or poisons taken by the victim prior to death.[74] This is especially useful when no blood is obtainable from the corpse for the same analysis. Unexpected entomological samples may also indicate that a body has been moved from its original location.

1.1.4.3.6 Paint

Pedestrian hit-and-run incidents also occur frequently in South Africa[26] and have the potential to leave traces of the offending vehicle (such as paint and glass) at the scene or on the body of the victim. Motor vehicle paint has many layers and databases do exist which list the specific colour layering of certain automobile paints to be able to link a paint chip back to a model or make of car.[75] A specific source can be identified if a physical match can be established.[75] Raman Spectroscopy of paint evidence has also been explored.[76]

1.1.4.3.7 Glass

Glass fragments are often encountered in burglaries and incidents involving motor vehicles.[77] Fragments can be matched by their refractive index or by the physical matching of break points.

1.1.4.3.8 Touch DNA

Perhaps the least apparent evidence of all is "touch DNA". DNA can be transferred from one person to another via physical contact.[78] Even brief skin contact can deposit DNA onto a touched surface.[79] People constantly shed imperceptible flakes of skin from their bodies due to the desquamation process of the epidermis.[80] Theoretically, these can be deposited on anything a person comes into contact with, be it objects, clothing or other people.[80] Skin particles are deposited by a single touch, rendering detection of this form of trace evidence potentially important for DNA analysis.[80] The sensitivity of PCR (polymerase chain reaction) means that even these tiny amounts of DNA can be amplified and used in an investigation. The main difficulty with using epidermal cells for analysis is locating them in the first place.[80] The concept of "touch DNA" revolves around the issues of abundance, transfer and persistence.[81] The minute nature of this evidence means it is difficult to detect even with the use of a dissecting microscope.[80]

Handled objects, touched surfaces and worn clothes were examined by Castella and Mangin (2008)[35] for DNA deposited during contact. It was found that the data obtained from these analyses has a high potential in aiding the crime solving process.[35] It has even been found that reliable DNA profiles can be obtained from lip prints on human skin.[82]

At least partial profiles and three full profiles were able to be obtained for all seven subjects who held plastic tubes for 10 seconds in a study by Djuric *et al.* (2008).[83] Mixed profiles were obtained from an experiment where subjects held each others' ankles for 10 seconds to test for the transfer of DNA from one person to another during physical contact.[83] Skin shedding status and hand dominance played a role, but two full DNA profiles were obtained even after 24 hours since deposition.[83] Rutty (2002) found that DNA was recoverable from the hands of an offender and the neck of a victim of manual strangulation at least 10 days after the incident.[58,84]

Other issues such as the effect of washing on evidence persistence and the possibility of innocent transfer through shared items or other non-violent contact needs to be researched.[58] It was found that background DNA levels on common burglary entry points are typically low, but the transfer of DNA during a subsequent burglary is also low.[81] As time passes, recovery of analysable DNA from outdoor surfaces is less likely.[81] Thirty-one percent of the swabbed locations gave a positive result in a study by Raymond *et al*. (2008).[81] Windows are a common entry point in burglaries but have low background DNA compared to other surfaces, making it a potentially good focus point for evidence recovery after a crime.[81] In simulated burglaries where volunteers held onto a clean doorframe, 40% of the frames returned some amount of DNA.[81] DNA was unrecoverable from the outdoor surface after two weeks.[81]

DNA-containing biological material can also be found under the fingernails of individuals.[85] The fingernails of non-violent death victims were swabbed to gauge the background levels of foreign DNA and gain an understanding for the applicability of mixed profiles found in violent deaths.[85] Foreign DNA was absent in the majority of cases.[85] Longer, cleaner nails produced better quality DNA profiles.[85]

The majority of violence – assault, rape and child sexual abuse – involves individuals known to each other; whether relatives, friends, or acquaintances.[26] This complicates issues of the relevance of "touch DNA" from individuals already in contact with a victim prior to the violent incident. How can it be proven that the evidence recovered is from the assault and not from daily contact? In a study by Raymond *et al.* (2008),[81] background swabs rarely revealed large alleles, meaning that if they are recovered at a crime scene, it might indicate more recent contact than the background DNA.

All these potential evidence types – especially the idea of "touch DNA" – suggest that the evidence is there, it just needs to be found. It is recognised that the absence of evidence does not mean the act did not occur, but discovery of even the smallest piece of physical evidence can give a struggling investigation more weight in the criminal justice system.

1.1.5 Tests

The forensic scientist is faced with two main tasks: locating the stain, trace or evidence particulate, and identifying it.[65] Screening and presumptive tests address the first issue, whereas confirmatory tests address the latter matter. Screening tests indicate the possible locality of evidence. Presumptive tests are merely screening tests which allude to a possible identity, whereas confirmatory tests can definitively identify a sample of questioned evidence with regards to its species of origin, categorization of material or nature and sometimes its origin or source.[55]

Various screening, presumptive and confirmatory tests exist to handle biological evidence.[86] One obstacle is that many tests are destructive in nature.[55] This means that a sample may be found and identified but cannot be further tested for DNA,[86] or that a sample is indeed present only in true trace amounts so that only one form of identification can be performed and extra samples cannot be retained for further analysis. When a sample is available in copious amounts, the need for a non-destructive method does not seem pressing, but when dealing with trace amounts, this aspect becomes very important.[87] False positives and false negatives are also issues that plague all presumptive and confirmatory tests.[55] Additionally, some tests can only be performed in a laboratory setting.[55] This wastes valuable time and money, and increases the possibility of loss or contamination between the crime scene and the laboratory.

DNA analysis is the most popular analysis to which a biological sample is subjected during forensic investigations.[87] This means it is very important to limit the damage and contamination to which the sample is exposed during preliminary identification procedures.[87] The potential value of biological samples warrants investment into a simple, rapid and non-destructive means of locating them.[87]

Other researchers also believe that the latest techniques and devices should be applied to the forensic discipline.[88] Colposcopes and endoscopes have been recommended to better visualise sinuses, cavities and genital injuries without the destruction of said structures during autopsy; and operation microscopes have been applied to the examination of clothing, among other things.[88]

Hand drawings are often used to document findings during a sexual assault evaluation, but some SANEs are beginning to incorporate photo documentation and the use of devices such as colposcopes and medscopes.[89] White and Du Mont (2009)[90] found that the use of micro-visualisation techniques by SANEs has led to some unintentional negative consequences. Objectification of the woman's body, emphasis on the discovery of injuries and causing confusion between which injuries are due to rape and which are due to consensual sex, are some of these negative consequences.[89] The equipment is sometimes considered intrusive and humiliating for the victim,[89] an issue which is less so in the case of deceased individuals. The short-term discomforts need to be outweighed by the long-term benefits of obtaining justice for the victim.[89]

1.1.5.1 Chemical Tests

1.1.5.1.1 Semen

There are several crime scene-ready chemical tests for prostate specific antigen (PSA) for semen, including Biosign® PSA,[91] OneStep ABAcard®[92] and SMITEST®,[93-94] but these tests are destructive to the sample and cannot be considered truly confirmatory as false positives are still possible.[55]

Allery *et al.* (2003)[95] compared tests which find zinc and acid phosphatase. The acid phosphatase test was very effective, whereas the zinc test gave disappointing results.[95] The acid phosphatase test may also be more sensitive in cases of azospermia and oligospermia than cytological methods.[95]

1.1.5.1.2 Blood

Improvements to luminol have been made over the years and it is still the most specific and sensitive presumptive test for blood.[96] Thorogate *et al.* (2008)[96] describe an immunoflourescent technique. The method developed by the authors is able to potentially detect minute droplets of human blood on dark fabrics.[96] It is fairly quick and easy to use and human specific.[96]

1.1.5.2 Imaging Modalities

The world of forensics is in need of tests which produce reproducible, reliable results and are non-destructive and portable.[55] The same applies for evidence detection equipment. Factors such as cost, ease of use and portability need to be considered when choosing imaging technologies for trace evidence recovery. Although screening tools will not provide confirmation as to the identity of a suspect stain or trace particle, they will indicate the approximate location where more intensive tests should be conducted.[97]

The destructive impact of a technique applied to evidence must always be considered.[55,98] Biological evidence can be removed during powdering and dusting processes, even if the powder itself has no effect on later DNA analyses.[99] Non-destructive and non-invasive techniques are always preferable when it comes to the detection and analysis of evidence.[98]

Portable equipment lends itself to use in the field or any room where its use would be beneficial. It is not limited to one location, meaning the difficulties of transporting or manoeuvring the body of a victim under investigation are eliminated.[100] The body and clothing can be examined *in situ*, minimizing disturbance of trace evidence.[100] The evidence in question is left untouched and can undergo sampling, testing and analysis as if the screening had never happened.

Some of the imaging technologies which fit the afore-mentioned criteria and therefore recommend themselves for potential use in the forensic medical setting are: the magnifying lamp, the portable digital microscope, the torch, and the ALS.

1.1.5.2.1 Magnifying Lamp

The idea that magnification aids an examiner in noticing details not apparent to the naked eye has long been known. Although there is no literature relating specifically to the simple magnifying lamp system proposed for use in this study, the iconic image of world-renowned fictional detective Sherlock Holmes wielding a magnifying glass is testimony to this. Trace evidence, by nature, is small in size and it seems a logical extension to explore the usefulness of a magnification system in the search for these traces. Magnifying lights similar to the one used in this study are typically used by kit model enthusiasts and jewellers for intricate work. Dermatologists and other medical practitioners are also known to make use of magnifying lamps.

1.1.5.2.2 Portable Digital Microscope

Much like the magnifying lamp, there are no specific research articles pertaining to portable digital microscopes in the field of forensics, but magnifying equipment already finds application in many disciplines.

In the field of dermatology, there have been new developments in the imaging of living skin.[101] Dermatologists make use of dermascopes and portable skin microscopes for the diagnosis of dermal lesions.[101] The use of new optical technologies serves to allow nonsurgical examination of *in vivo* skin pathologies.[101]

Another optical enhancement device, the colposcope, has been proposed as a tool to better evaluate genital trauma in victims of sexual assault.[102] The colposcope found injuries in 53% of victims, whereas gross visual examination found injuries in only 6%.[102] The colposcope has a light source and offers binocular magnification, with some models having photographic capabilities.[102] It was originally designed to examine female genital pathology.[102] It has also been used for examining paediatric victims of sexual assault previously.[102] Lack of training and unavailability of equipment have limited the colposcope's use on adult victims of sexual assault.[102] According to Rambow *et al.* (1992)[45], documentation of trauma and other physical findings (semen, hair, *etc.*) during a sexual assault examination is significantly associated with more prosecutions. Another study confirms the usefulness of the colposcope for documenting genital trauma in rape victims, with a rate of 87% positive findings.[103] These examples only go to show the potential of this type of equipment for close-quarters examination of human skin with a view towards discovering elusive evidence.

Portable digital microscopes typically offer at least 150x magnification and 2-5 megapixel image resolution. They allow fast, simple inspection of almost any surface.[104] Connection to and subsequent recording of images by a computer overcomes the limitations of the human memory.[105]

1.1.5.2.3 Torch

Similarly, there is no literature describing simple handheld white light torches, except where the usefulness of oblique white light for highlighting impression and particulate evidence is mentioned. Oblique lighting can be employed to locate fibres on a surface using a powerful white light.[106] Shoeprints, dark hairs and crusted-over dry fluids are well-suited for discovery by oblique white light.[106]

It also seems logical that a well-lit environment will be better suited for investigation purposes. In addition, the aim is to disturb as little as possible at a crime scene, so it would be preferable to use a strong torch to illuminate a room rather than contaminating light switches which may need to be swabbed for evidence. This study merely proposes the potential of a quality, high intensity white light torch which can be easily incorporated into every crime scene officer's investigation kit with minimal costs incurred.

1.1.5.2.4 Alternate Light Source (ALS)

The ALS, on the other hand, has extensive mention in scientific literature, which seems fitting as it is the most expensive and complicated equipment explored here.

An ALS – also known as an FLS (forensic light source) – refers to an illumination system applied in a forensic setting.[107] This includes lasers and other high-intensity lamps,[107] but the term "ALS" usually refers to a non-laser FLS.[107] These illumination systems work either by causing a sample to fluoresce, or by increasing the sample's contrast with its background/substrate[108] Both methods make a sample more visible to the observer. Fluorescence occurs when the sample is exposed to the illumination source and absorbs light at one wavelength (excitation spectrum) while re-emitting the absorbed light at a longer wavelength.[107] In layman's terms, fluorescence is when a sample glows, absorption is where a sample appears darker, and oblique angled lighting reveals particulate evidence.[106]

Fluorescence occurs immediately when a subject is exposed to the light source, and ceases immediately upon removal of the light source.[109] This is in contrast to phosphorescence where a sample will continue to glow for a certain period of time after the light source is removed. ALSs are in common use in laboratories (both local and international) to guide the examination of clothing and other fabric exhibits.[110] An ALS – the Polilight® (Rofin Australia) – was purchased several years ago by the SAPS for use at crime scenes and in the evidence recovery section of their biology laboratories, but is only now starting to be introduced into routine examinations. Many drawbacks have made ALSs impractical for regular scene use in the past, but improvements have since been made.[111]

An ALS is a high intensity light source using a bulb which emits light in the visible, UV (ultra-violet) and IR (infra-red) spectrums.[106] It has filters which allow for the selection of specific wavelengths best suited for evidence enhancement.[106] Shortwave UV refers to 190-290nm, longwave UV is 290-400nm, 400-430nm is violet light, 430-490nm is blue, 490-575nm is green, 575-590nm is yellow, 590-620nm is orange, 620-700nm is red, and above 700nm is IR light.[106] As wavelength increases, energy output decreases.[106] Exposure to the high-intensity radiation emitted by an ALS is damaging to the eyes, and possibly the skin (UV for example).[106] For this reason, protective goggles must be worn and the light should never be looked at directly.[106] The fluorescence emitted by an illuminated subject is always much weaker than the light used to excite it.[109] This is the reason why it is necessary to filter out incident light and allow viewing of only the emitted light.[109]

Tuneable light sources are useful for the macroscopic examination of a crime scene.[80] ALS systems are only able to act as screening tests to indicate likely areas where biological stains may be found and cannot be relied upon to identify or distinguish biological fluids.[55]

The use of an ALS is by no means a confirmatory test, or even a presumptive test. By using an ALS exhibits can be searched for evidence without having to handle the surface in question, thus reducing the chance of dislodging traces, smearing prints or contaminating the sample.[106] Fluorescence helps to focus the examiner's attention on small key areas that should be swabbed, as opposed to blindly swabbing large areas.[112]

The white light band is recommended for general searching and specifically footprints. Three-hundred-and-fifty nm (UV) is recommended for general searching of stains and fingerprints.[113] Four-hundred-and-fifteen nm is referred to as the blood filter and is recommended for blood prints, blood splatter and gunshot residue.[106,113] Light-coloured hairs can be illuminated with light set to 415nm.[106] Four-hundred-and-fifty nm is recommended for the general searching of semen, urea and fibres.[113] Bone and teeth can be seen with 455nm or 515nm.[106] Four-hundred-and-seventy nm is recommended for general searching and ninhydrin[b]-developed prints.[113] Four-hundred-and-ninety nm is for semen, urea and fibres.[113] Five-hundred-and-five nm is recommended for superglue (cyanoacrylate) - and ninhydrin-treated prints.[113] Five-hundred-and-thirty nm and 555nm are suggested for DFO-treated prints and background reduction.[113] Five-hundred-and-ninety nm, 620nm and 650nm are suggested for ninhydrin-treated evidence and background reduction.[113] Saliva and dark surfaces require UV light, and bite marks and bruises can be seen under 415nm, 445nm, 450nm, 515nm, 535nm, 555nm or 575nm.[106,115] IR is recommended for document examination.[113]

Goggles are used to filter out the strong excitation wavelength and allow observation of only the emission spectrum.[116] The ideal goggles-to-wavelength combination is achieved when the background is not observably photoluminescent.[116] Goggles are used to block out any reflected incident light and the shade to be used gets darker as the wavelength used gets longer.[80] As a rough guide, 350-415nm needs to be viewed with yellow goggles,

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[b] Ninhydrin or 1,2,3-triketohydrindene hydrate has a strong reaction with sweat which allows the development of latent fingerprints.[114]

450-505nm needs orange goggles and 530nm and above needs red goggles.[113] UV light does not require coloured goggles, but those that offer UV protection (clear goggles) must be worn for protection.[117] A similar concept which is purported to be more effective than the goggles is that of interference filters.[118] Interference filters use an interference effect to transmit light at one wavelength and reflect other wavelengths.[118]

The best general wavelength and goggle combination for detecting biological stains is 450nm with orange goggles.[113,119] Almost all stain types were detectable on white cotton using this combination.[119]

An ALS is either mains-powered or battery-operated. The ALS does not pose any known harmful effects to the user except when operated in the UV range[120] or when the high intensity beam is looked upon without the provided protective eyewear.[113] It is purported to successfully locate saliva, seminal fluid, blood stains, both "raw" (undeveloped) or developed fingerprints, as well as other stains which are not visible to the naked eye.[119] ALSs are known to enhance stains for photographic purposes, even when they do not perform as well as other screening tests in terms of detection.[120]

The ALS is deemed to be safe, fast, simple to use, non-destructive and non-invasive.[80,119] The use of an ALS claims to speed up evidence detection considerably[80] as it is used to narrow down large search areas to defined regions where useful samples may be taken.

The identification of biological evidence at a crime scene is important for an investigation.[86] Biological evidence is most typically coveted for its potential to yield DNA.[86] ALSs have been used for this purpose.[86,112] The ALS is considered to be one of the simplest methods for the on-site location of biological evidence.[55] The technique is considered to be a straightforward and non-destructive screening test for most types of biological evidence.[86]

Bodily fluids are naturally fluorescent, and ALSs exploit this property in order to locate them.[106,117] Semen, vaginal secretions, urine, sweat and saliva all possess some fluorescent capabilities.[117] It should be kept in mind that laundry detergents are known to fluoresce and may influence the ability to accurately detect stains with true evidential value.[80,119]

1.1.5.2.4.1 The ALS and Blood

Blood is known to absorb light, whereas samples such as semen and urine are detectable by their fluorescent capabilities.[86] Untreated dry blood does not fluoresce noticeably, but has a high absorption band from 300-900nm (this encompasses UV, visible and IR light).[116] For this reason, bloodstains are seen as dark spots when exposed to any wavelength.[86] It was found that most ALSs appreciably enhance the contrast of bloodstains to their background, aiding in their detection and visibility.[55,107-109,116,119,121-127] This effect was most noticeable on dark backgrounds where bloodstains would appear brighter in comparison.[107] Blood's absorption is strongest between 395nm to 435nm, and is optimal at 415nm.[86] A Rofin PL-10 Polilight® (a high-intensity xenon lamp) was used to determine these values.[86] This particular product can emit light at 435nm, 415nm and 395nm.[116] The Polilight® is able to detect bloodstains masked by paint.[119] IR light can also successfully detect bloodstains on black fabrics.[122] Wawryk and Odell (2005)[109] reported that bloodstains were detectable on skin using high intensity LEDs or the Poliray™, but not after the first day of deposition.

Several ALS systems have been reported as suitable for detecting bloodstains. This includes UV[123,125], high intensity LED,[109] the Lumatec® Superlite 400[124], Poliray™[109] and Polilight®.[55,107,116,119,121,126-127]

When comparing maximum blood dilutions detectable, the Polilight®[119,126-127] out-performed the Lumatec® Superlite 400[124] between 10 and 100-fold; with both far out-performing high intensity LEDs,[109] the Poliray™[109] and IR light.[122] When the Polilight® PL500 was used on white cotton, blood could be detected up to 1/1000 dilution.[119] This had little bearing, however; as these stains were readily visible with the naked eye, rendering the benefit of the ALS for blood detection on light-coloured surfaces minimal.[119]

1.1.5.2.4.2 The ALS and Semen

Semen is highly fluorescent and can be visualized on both dark and light surfaces under a high intensity UV light.[117] Semen has a broad excitation spectrum, meaning that it can be caused to fluoresce under a range of wavelengths.[110] This allows fine-tuning to minimize background interference and enhance contrast of the stain and substrate.[110] Stoilovic (1991)[116] reports the excitation spectrum of a semen stain in the 300-480nm range when illuminated with a Polilight®. Nelson and Santucci (2002)[111] used an Omniprint™ 1000, which is a light source with adjustable wavelengths between 320nm to 510nm, accompanied by yellow, orange and red goggles. They found that semen fluoresces optimally when excited with 420nm-450nm and viewed with orange goggles.[111]

Wood's Lamp is a UV source and is purported to cause semen to fluoresce, recommending it for use in sexual assault evaluations.[128-129] Contrary to this, Santucci *et al.* (1999)[130] found that none of the semen samples (29) examined in their study fluoresced under illumination from Wood's Lamp; regardless of being wet or dry. Interviews with supplying companies revealed that they all recommended the use of Wood's Lamp, and at the wavelength used (360nm), for the detection of semen in sexual assault examinations.[130] It is believed that the optimal wavelength for the fluorescence of semen is longer than the product used provided.[130]

The Bluemaxx™ BM500 (390-500nm) is purported to out-perform Wood's Lamp[111] and can detect semen stains on white cotton 100% of the time. Lincoln *et al.* (2006)[112] reported successful semen detection using the Poliray™ with a 550nm camera filter.

Santucci *et al.* (1999)[130] also found that illumination from Wood's Lamp was unsuccessful in distinguishing between semen and other samples. Only 22% of the physicians questioned had received formal training in the collection of forensic evidence.[130] None of the physicians were able to successfully distinguish semen from other products with the use of the Wood's Lamp.[130] It was also found that after some brief training, over 80% of physicians were able to competently differentiate semen from other samples, although an ALS is still not viewed as a true presumptive test (United States of America).[111]

Wood's Lamp was typically used for sexual assault evaluations without any experimental verification to advocate this use.[109] Wood's Lamp emits UV light but is used on living patients. An ALS set to emit light at 490nm was far more effective in causing semen to fluoresce than the 360nm used with the Wood's Lamp.[130] Santucci *et al.* (1999)[130] suggest Bluemaxx™ 500 (Sirche Finger Print Laboratories, Inc, Raleigh, NC) as a possible better alternative.

The Bluemaxx™ BM500 was used and was found to be able to cause semen to fluoresce.[111] Training of the physicians in the use of the Bluemaxx™ 500 increased the sensitivity of the method more than threefold.[111] This particular ALS is not specific for semen but is 100% sensitive for it.[111] It was determined with the use of the Omniprint™ 1000 forensic light that dry semen fluoresces optimally at 420nm and 450nm, viewed with orange goggles.[111] Thirty-one percent of the participating physicians in the study by Nelson and Santucci (2002)[111] had received prior training in sexual assault evaluations and forensic evidence collection. The fluorescence quality of a semen sample remained constantly intense up to a 16 month time period.[111] According to Gabby *et al.* (1992)[128] the fluorescence of semen changed with time, which is different to what was found by Nelson and Santucci (2002).[111]

The investigation of sexual assault cases is often focused on the location of seminal fluid stains (Australia).[110] Fluorescent approaches are popular especially when searching large items like duvets and sheets. One drawback of this method is that a negative result cannot conclusively exclude the presence of semen.[110] Fluorescence of stains can be difficult to discern on some types of fabric.[110] Kobus *et al.* (2002)[110] used the Polilight® PL10 (Rofin Australia) to search for semen on fabrics involved in sexual assault cases. They aimed to improve the efficiency of fluorescent detection of semen.[110] Dried seminal stains of various dilutions were examined on typically difficult fabrics.[110] A significant improvement in observation of fluorescence was seen when the stains were viewed through interference filters instead of coloured goggles.[110] Kobus *et al.* (2002)[110] have since had goggles made that use band pass filters as lenses.

According to Vandenberg and Oorschot (2006)[119], semen was best detected at 450nm using orange goggles. Imperceptible semen stains appear to be detectable on most surfaces owing to the strong fluorescence of the biological fluid.[119] Strongly fluorescent substrates, such as white cotton, pink satin and pink fleece, impair the contrast with semen, making it more difficult to detect.[110] The excitation and emission wavelengths of these materials mean that different wavelengths are better suited for the detection of semen on these materials.[86] For example, 450nm performs better than UV when examining semen on white cotton.[110] Wood's lamp was unsuccessful in detecting semen on white or black cotton for similar reasons.[130] The Bluemaxx™ BM500, which emits light at 450nm, is therefore better suited for semen detection on white cotton.[111]

When it comes to semen dilution detection, the Polilight®,[110,119] Lumatec® Superlite 400,[124] and Spectra-Physics® Reveal™ laser[124] perform comparably; with each performing better depending on the substrate. The maximum detectable dilution of semen by the Polilight® on white cotton is 1/100.[119] The Lumatec® Superlite 400 and the Spectra-Physics® Reveal™ laser performed comparably when detecting semen stains on different surfaces, regardless of dilution.[124]

An interesting finding was that the fluorescence of old semen stains increased after washing.[110] The stains that fluoresced weakly after washing did not respond to the acid phosphatase test, meaning that the fluorescent components are more resilient.[110] Once semen has been absorbed into fabric, it cannot be enhanced by exploiting the excitation or emission bandwidth capabilities.[110] This problem is most noticeable if a stain is diluted.[110]

1.1.5.2.4.3 The ALS and Saliva

Saliva is particularly hard to see with the naked eye once dried as it is virtually colourless,[118] making the ALS beneficial in its ability to narrow down large search areas so that DNA retrieval can be attempted.[119] Saliva is known to fluoresce, but not to the strength or degree seen with semen; rendering saliva stains more difficult to detect with ALSs compared to semen stains.[118] It is detectable under UV excitation.[124] Saliva is also visible when excited with short UV (266nm)[125] and 450nm illumination with orange goggles.[119]

On a white cotton background, Camilleri *et al.* (2006)[118] found that saliva fluoresces optimally at 470nm with 555nm interference filters. Other effective combinations were 415nm with yellow goggles or 555nm interference filters, 470nm with 530nm interference filters, 490nm with 555nm interference filters, 505nm with 555nm interference filters[118] and 532nm with goggles designed to block 532nm.[124]

1.1.5.2.4.4 The ALS and Urine

Urine stains are difficult to see as they spread and become diluted on fabrics.[55] Urine may contain other fluids or particulates that can be used for DNA analysis.[117] Urine can be observed under UV luminescence,[131] 415nm with yellow goggles,[119] 450nm with orange goggles,[119] and 505nm with red goggles.[119] Seidi *et al.* (2008)[124] observed urine at 532nm viewed with goggles designed to block 532nm light using the Spectra-Physics® Reveal™. Urine is also purported to fluoresce under Wood's Lamp illumination.[128]

There are not many studies relating to the maximum detectable dilution of urine on different substrates.[86] Urine is reported to be detectable on white cotton using the Polilight®, but serial dilutions were not offered in the study by Vandenberg and Oorschot (2006).[119] Seidl *et al.* (2008),[124] however, reported the detectable dilutions for the Spectra-Physics® Reveal™ laser and the Lumatec® Superlite 400.[124] These two systems were found to perform comparably for the detection of urine stains. The Mineralight® was able to detect urine on skin with 71% sensitivity, and the Bluemaxx™ BM500 with 14% sensitivity.[132]

1.1.5.2.4.5 The ALS and Fingerprints

Another one of the primary applications of an ALS is the detection of latent fingerprints.[106] At present, this requires enhancement procedures (such as powders or stains) which work in conjunction with the light source to reveal latent prints from a number of different surfaces for photographic purposes.[106] The use of ALSs for this application has been particularly successful on typically troublesome surfaces where sufficient detail may not be obtained using traditional techniques.[106]

1.1.5.2.4.6 The ALS and Other Evidence

The ALS may also help in locating faint bruises which could be of importance to possible non-accidental injury syndrome (child-abuse) cases.[133] ALSs can reveal otherwise invisible bruises or patterned injuries which could go towards indicating weapon type or extent of injury.[106] Other patterns such as bite marks and shoe prints can aid in identifying a suspect and linking them directly to the victim.[106] Gunshot and explosive residues are also known to fluoresce which can help to determine range of fire and possibly indicate the shooter from residue found on a suspect's hands or clothing.[106] Questioned documents can also be illuminated with an ALS in order to reveal inconsistencies in ink formulations; suggesting counterfeicy.[106] Fibres and hairs will fluoresce under UV or other wavelength illumination.[106]

Sweat can usually be seen with a high intensity UV light on surfaces such as the insides of gloves or balaclavas (woollen ski masks).[117] Bone fragments and drugs are also known to fluoresce, meaning that an FLS can find application in many disciplines.[106] FLSs are even finding application in arson investigations.[106] Vaginal secretions are elusive as they fluoresce very poorly, even under high intensity light.[117]

1.1.5.2.4.7 The ALS and Chemical Counterparts

One finding is that an ALS is less sensitive at detecting biological fluids than its chemical counterparts, such as luminol.[86] This means that it is less likely to detect lower dilutions of samples and that some truly trace amounts can be missed with this method. A Polilight® can detect a bloodstain at a maximum dilution of 1/1000,[119] whereas luminol can detect dilutions up to 1/5000000.[121] The ALS manages to successfully detect seminal fluid diluted to 1 part in 100.[119] This has relevance to case work where exhibits may have been washed or exposed to rain before examination.[119]

1.1.5.2.4.8 The ALS and Multiple Wavelengths

To achieve optimum sensitivity with an ALS, it must produce light of a high-intensity. Wawryk and Odell (2005)[109] found that light systems of lower intensity are unable to detect urine as it emits light very weakly. Because each evidence type and each surface requires different wavelengths to achieve optimum enhancement, FLSs offering a tuneable system or multiple wavelengths are popular.[106] Each substance has its own wavelengths which allow optimum detection, and no one wavelength encompasses all evidence types.[86] There are many overlaps so, to date, an ALS cannot be reliably used to make inferences as to a substance's identity based on its excitation wavelength alone.

1.1.5.2.4.9 UV and IR

UV light receives much attention in discussions of trace evidence collection.[116,134-139] UV is said to be able to cause most/all body fluids to fluoresce but so will their background substrates, meaning that different wavelengths are required to produce the desired contrast.[106]

It has long been known that black light (long-wave UV) will cause many products, including semen, to fluoresce.[134] Ito (1927)[135] reported that several bodily fluids fluoresce under UV light. UV light applied in the crime scene setting has been described previously.[116,138-139] It is suggested that UV light be used to indicate areas of interest at a crime scene.[117]

The use of a UV light source is purported to make the daunting task of biological evidence detection easier.[117] The Labino® UV light is a high intensity light source that boasts being able to be used in undarkened rooms while still offering high subject-to-background contrast.[117]

IR light, on the other hand, is under-reported. IR light is between 760 and 1500nm. IR light has been used to detect gunshot residue,[140] inks[122] and to examine documents,[141] bloodstains,[142] and bite marks.[143-144] IR is considered to be an under-utilised tool in the detection of latent evidence because photography of the illuminated exhibits is difficult.[122] Visualizing evidence with IR light requires IR sensitive film or an IR camera for photographic purposes.[106] It is believed that IR light can offer the same advantages as UV and ALS methods.

1.1.5.2.4.10 The Polilight® PL500 versus Other Models

The Polilight® is the most tested ALS in the literature as it offers high intensity light and multiple wavelengths.[86] Vandenberg and Oorschot (2006)[119] tested the Polilight® PL500 (the same model used in this study) on blood, semen, urine and saliva, and proved that the system could detect all these evidence types when viewed with the suitable goggles.

Wawryk and Odell (2005)[109] compared the detection capabilities of different types of LED and the Poliray™ for blood, semen, saliva and urine on skin. All of the tested systems could detect blood and semen, but operation at close-range to the work surface (less than 3cm) was necessary, as well as an observation range within 20cm from the sample.[109] Saliva did not fluoresce under illumination from any of the tested light sources. All of the tested systems are of lower light intensity than the Polilight®. This rendered saliva detection very difficult as it only has a weak fluorescence under the Polilight®. Urine was undetectable by any of the lower-intensity LEDs or the everLED™ Maglite™. Urine was vaguely perceptible when illuminated with Luxeon™ Labino® Star V LEDs and the Poliray™.[109] The Spectra-Physics® Reveal™ laser and Lumatec® Superlite 400 perform comparably in the detection of diluted saliva and urine.[124]

Carter-Snell and Soltys (2005)[132] compared the Mineralight® (254nm), Evident Products CE (365nm), Bluemaxx™ BM500 (450nm) and Bluemaxx™ Mini (450nm) for their ability to detect semen, urine and saliva. All of the ALSs tested could detect semen.[86] Only the Mineralight® and Bluemaxx™ BM550 were able to detect urine, and all but the Bluemaxx™ Mini were able to detect saliva. The Bluemaxx™ Mini has a lower light intensity, making it the weaker illumination system. An interesting note from the study by Lee and Khoo (2010)[86] is that the same semen stains were reported as different colours depending on the examiner despite using the same tool and goggles. This enforces the unlikelihood of being able to definitively identify and differentiate different stains based on their apparent colour-under-illumination alone and firmly categorizes the ALS as a screening tool rather than a presumptive test.

1.1.5.2.4.11 The ALS and Surface

The ability to detect biological stains using an ALS is highly sensitive to the surface on which the sample is deposited.[86] Different substrates react differently to each illumination system.[86] Lee and Khoo (2010)[86] examined the methods and factors that affect detection of biological evidence by ASLs. The colour, absorbency and inherent fluorescence capabilities of the substrate all influence the visibility and enhancement of the deposited fluid.[9] Most studies using ALS systems focus on inert substrates which limits its applicability to the examination of human skin.[109] It is believed that stronger light sources may be more effective at revealing semen on skin, but the potential damage this intensity of light may cause to the skin needs to be considered.[109]

Absorbency of the substrate was found to be a factor in determining detectability.[119] Highly absorbent substrates mask the stain with their own fluorescence as the fluid has receded into the background material.[86] Interestingly, absorbency did not appear to greatly negatively impact semen stain detection by the Polilight®, but the colour and pattern of the surface seemed to affect the stain appearance.[119] Patterned fabrics made saliva stains particularly elusive.[119] The Polilight®'s maximum dilution detected for saliva on white cotton was only 1/16.[119] Saliva on skin was found not to fluoresce when viewed under high intensity LED or the Poliray™.[109] UV light, however, was found to be extremely effective in detecting saliva on human skin, with saliva being 100% sensitive to UV light produced by the Mineralight® (254nm) and Evident Products CE (365nm).[132] Only 14% sensitivity was seen with the Bluemaxx™ BM500.[132]

Using different wavelengths to reduce background interference is known as background rejection.[106] The more intense the light source and the more wavelengths at your disposal, the better your chances of recovering more evidence in both quantity and type.[106] Background correction methods (multispectral imaging algorithms), as proposed by Wagner and Miskelly (2003),[126-127] are purported to improve the Polilight®'s detection of lower dilutions of blood. This could offer a means of eliminating inter-observer variability in reporting and add precision to the process.

1.1.5.2.4.12 Alternatives to the ALS

Lasers (such as TracER™ and Spectra-Physics® Reveal™) produce light of a higher intensity compared to most ALSs, and offer a narrower bandwidth.[86] This means that lasers should be more efficient in evidence detection than other forms of light sources.[108] Auvdel (1987)[145] conducted a study which showed that a laser (the Spectra-Physic® Model 171-19) was more effective than a short UV light source (the Mineralight®) in detecting semen, saliva and sweat stains. In another paper by the same author[146] however; it was reported that the Luma-Print (a high intensity quartz arc tube) out-performed the Spectra-Physic® Model 171-19. The Luma-Print is also more portable than the laser, recommending it for crime scene work. Lasers are typically more expensive and heavier than other ALSs.[108] Seidl *et al.* (2008)[124] compared the Lumatec® Superlite 400 (a tuneable ALS) and Spectra-Physics® Reveal™ (a laser system) for their ability to detect blood, semen, saliva and urine. The light sources produced comparable results but urine fluoresced noticeably more under illumination by the laser system, and blood could not be detected with the particular laser system.[124]

Lasers were traditionally confined to laboratory work as they are large and require cooling equipment.[106] They have since become more portable but are still limited to only one wavelength.[106] A laser cannot be used to reject background interference or enhance contrast, meaning that many evidence types will go unseen.[106]

The wavelengths produced by lamps and LEDs shift as the light source ages.[147] This problem is not encountered with lasers.[148] Lasers are significantly brighter than lamps and LEDs.[148] It is not necessary to increase the source size in order to increase a laser's power.[148] New developments in laser technology have meant a reduction in power consumption, wider wavelength selection, higher output, and a potential for mass production.[148]

Reviews on LEDS are mixed.[106,109] The use of LEDs promises a reduction in size, weight, cost and power requirements, while increasing portability and lifetime.[109] The cheaper the LED, the better the portability but the lower the versatility.[106] Previously, LEDs have only been available in a limited range of wavelengths at very poor light intensity, but improvements on this technology have also since been made.[109] When configured to offer more wavelengths, price goes up considerably, and can sometimes exceed the cost of a better designed ALS.[106] The multi-wavelength option on an LED light source means that cumbersome changing of parts is required.[106] LEDs also provide a diffuse light spot, making them ideal for searching a large room, but less than ideal for photography of specific exhibits.[106] They experience limits regarding background subtraction.[106] It is now possible to select the LED which will best suit the application, without needing the tuning filters used in expensive ALS systems.[109]

An ALS is considered by some to be the perfect compromise of cost, power and versatility.[106] One portable laser equates to the cost of several better equipped ALS systems.[106] ALSs are also believed to be easier to use than lasers.[106]

Lasers have the highest power but are the most expensive option and are the least versatile.[106] LEDs are the most affordable but are low powered and lack versatility.[106] ALSs are high powered, versatile and moderately priced.[106] Lasers have the power, LEDs have the affordability, but ALS systems mix these components with versatility.[106]

Wawryk and Odell (2005)[109] tested various LEDs with emission wavelengths between 370nm and 480nm and compared them to a Poliray™ ALS. Semen, urine, saliva and blood were tested alongside other confounding products such as lubricants and creams.[109] The substances were allowed to dry before examination and the examinations were conducted in a darkened room.[109] All the test subjects were White.[109] The low-powered LEDs were unable to induce fluorescence in the semen.[109] The everLED™ Maglite™, the Luxeon™ LEDs, and the Poliray™ were able to excite some fluorescence from the semen, but it was extremely feint to invisible on the second day of examination.[109] Saliva did not fluoresce under illumination from any of the light sources.[109] Urine did not fluoresce under any of the weaker LEDs or the everLED™ Maglite™.[109] Unlike semen, urine does not dry with a crust, meaning it is not visible via reflection in the same way that semen is.[109] Urine did not fluoresce on the second day.[109] The pigmentation of blood made it readily apparent under all of the light sources but none could be detected on the second day.[109] None of the potentially confounding products (lubricants and hand creams) fluoresced under any of the light sources.[109] It was necessary to hold the light source extremely close (<3cm) to the surface in order to appreciably view the fluorescence of the semen.[109]

1.1.6 Clinical Application

For every case that enters the doors of the PMLL, a significantly higher proportion of individuals are victims of similar crimes yet survive to avoid our examination. It would be ideal to pinpoint an imaging technology which not only suits our purposes in the crime scene and mortuary settings, but can also be extended to find applicability in the clinical environment.

Lincoln *et al.* (2006)[112] looked at the application of the ALS in the clinical forensic setting (Australia). Tests were conducted on inanimate surfaces as well as human skin.[112] It was found that visibility increased with a decrease in distance between the light source and the surface, as well as with an increased concentration of semen.[112] The angle of the light source in relation to the surface did not have a major effect on visibility.[112] Examples are given of case studies where ALS-directed swabbing was undertaken and semen was found in greater abundance than that which was found with routine swabbing.[112] The ALS is not semen-specific and any dried biological fluid has the potential to fluoresce.[112] Routine swabbing of larger general areas as opposed to smaller ALS-defined areas increases the chances of picking up the subject's epithelial cells and thus providing a "less pure" semen sample.[112] Surrounding blood was found not to interfere with the location of fluorescent samples as blood shows up dark at 450nm.[112]

Clinical forensic examinations of rape victims are on the increase.[149] Genital injuries are relatively rare in cases of sexual assault,[150-151] so other evidence such as seminal fluid becomes invaluable. One study by Jewkes *et al.* (2009)[152] found an association between the documentation of injuries and conviction in sexual assault cases in South Africa, and the authors suggested that training of forensic medical examiners should be prioritized over investment in expensive DNA analysis systems.

Semen, lubricants and moisturizers were deposited on human forearms and illuminated with an ALS.[109] None of the substances fluoresced on the majority of the volunteers.[109] Semen and urine were found to weakly fluoresce under the more powerful lights on a few of the volunteers.[109] In these cases, there was a noticeable difference between the urine and semen samples.[109] Semen was also deposited on fabric and was found to fluoresce well.[109] Wawryk and Odell (2005)[109] concluded that an ALS is effective for the detection of semen on clothing but has limited application on human skin.

Schulz *et al.* (2007)[80] found that skin particles fluoresce best under light of about 390nm and 475nm, with greasy skin particles fluorescing more intensely than dry particles. This factor was particularly useful in distinguishing skin flakes from stone or crystal flakes, which are easily confused under natural light.[80] This effect was not so pronounced when searching for skin imbedded amongst fibres, and the only improvement to discovery was time.[80] The fibres' own fluorescent qualities interfered with the skin flake detection and the ALS was not of great help.[80] Despite the benefits of this technique, a skilled examiner is still required to make accurate assertions.[80] The success of this technique also relies on the fluorescent properties of the background material.[80]

ALSs have been known to reveal faint or invisible bruises on the skin of victims of violence.[115] A Polilight® PL10A (Rofin, Australia) operated at 415nm and 450nm was used to illuminate bruises with an aim towards attempting to determine the age of the said lesions.[133] It was found that the Polilight® was unable to aid in age determination of bruises.[133] The study was only conducted on fair-skinned (White or Asian) individuals.[133] Injuries examined with an ALS have been found to reveal greater detail, contrast and extent than examination with the naked eye under normal lighting.[153]

The use of an ALS does not seem to have much of a negative impact on subsequent DNA analysis[154-155] and is deemed a safe, simple, non-invasive and non-destructive tool for the screening of scenes and exhibits.[80] The torch, digital microscope and magnifying lamp have no known health risks. ALS systems are also purported to pose no health risks to the user – if the correct eyewear is worn – and are even recommended for the clinical forensic setting.[128-129] The issue of exposing living individuals to UV light in this context is not addressed much in the literature.[132] The danger of prolonged exposure has been mentioned,[156] but ALSs emitting light at 400nm and over are considered relatively safe.[132] One can assume that, much like X-rays, the benefit of using an ALS to find trace evidence needs to be weighed against the potential harm it could cause the patient before it is simply used with reckless abandon.

1.1.7 Potential of Imaging Technologies

All of the above-mentioned imaging technologies are non-destructive and fairly simple to use. Each offers its own potential for improved evidence detection. These tools therefore recommend themselves for potential use in the forensic setting.

According to Rambow *et al.* (1992),[45] the potential to exonerate an innocent party or convict a guilty assailant should outweigh the frustrations of tediously collecting evidence that may not be analysed or may not produce useful results. Should these imaging technologies prove viable in the post mortem setting, their usefulness must be extended to potentiate equally thorough forensic medical examination in the clinical setting.

If investment into these and similar technologies can serve to even slightly improve the success rate of judicial proceedings, then we should be investing in them. This would be unwise, however, without sufficient prior research – such as this – into the efficacy of these investments under field conditions. Empirical studies such as this one have not been conducted in South Africa. In treating the body as a secondary crime scene, valuable clues as to the circumstances of injury or death can be discovered. With an investment of slightly more time, effort and money, the potential to improve the administration of justice through the use of these and other technologies in both the post mortem and clinical settings is too immense to be disregarded.

Although the idea of searching for traces of contact between victim and assailant is not new, it is an area that still requires much exploration in order to find the best techniques and equipment for efficient and effective evidence recovery. As yet, no one system has been designed to suit all evidence discovery needs, and current screening tests are still lacking in sensitivity and specificity. It is necessary to explore the effectiveness of simple, affordable yet efficient evidence imaging technologies to discover one, or a combination of as few as possible, that suits our needs and resources in the South African context. The consequences of not collecting the available forensic evidence when the opportunity presents itself can be severe and means that more research is needed in this area to avoid wasted opportunities and the miscarriage of justice.[58]

Despite the resource limitations that apply to developing countries such as South Africa, the acquisition and application of appropriate equipment to medico-legal investigation is justified; provided that research such as this can show that it adds value and is not resource-draining. There are innumerable types of equipment and technical advances developed for forensic use; the challenge is to identify, find and use them. These and similar tools could empower the investigator or forensic scientist to find, document and ultimately bank invaluable information.

Although the results of this study may be difficult to quantify, it is hoped to have the effect of stimulating further studies and academic debate. This research may assist us to further integrate technical developments into the world of South African forensic medical investigation. This country should and does provide a fertile land for people interested in working in the field of forensics; with the high crime rate, scientific rigour and multitude of institutions in place. We must rise to the occasion and use the opportunities afforded us.

Chapter 2: Materials and Methods

2.1 Setting

The study took place at the Pretoria Medico-Legal Laboratory (mortuary)(PMLL). This facility was selected as it is academically associated with the University of Pretoria and caters to a large case load annually. The PMLL serves the majority of the Pretoria area (approximately 2500 cases per annum), with a small portion of the case load (in the region of 1500 per annum) being admitted to two other medico-legal facilities. The PMLL performs autopsies on all deaths due to other-than-natural causes as legislated in the Inquests Act 58 of 1959.[157] Duties include 1) attending the scene where feasible, 2) conducting the autopsy and 3) performing specialized investigative techniques. Permission and authorisation to conduct the proposed study were sought from the University of Pretoria's Faculty of Health Sciences' Research Ethics Committee (See Annexure A), the MSc Committee (See Annexure B) and the relevant authorities at the PMLL.

2.2 Case Selection

Cases of expected contact fatal interpersonal violence were examined. This comprised mainly of victims of homicidal blunt-force and sharp-force trauma. According to recently published data from a previous study,[19] these cases could be in the region of 300 per annum at the PMLL. Cases of manual strangulation and ligature strangulation were also considered; essentially any case where it was considered by the researcher and/or attending pathologist that there may have been some sort of violent struggle resulting in a possible transfer of physical evidence. A number of pedestrian-vehicle accident (PVA) cases were also considered, as evidence from contact with the offending vehicle was expected to be found on the victims and prove particularly valuable in cases of hit-and-runs.

Cases where perpetrator-victim contact was expected to be minimal were excluded from consideration; for example gunshot-wound victims and vehicle occupants of road-traffic accidents. Individuals who were hospitalized over any length of time were also excluded as it was expected that any relevant trace evidence would have been washed away, disturbed, or mixed/contaminated with that of the attending medical staff. Case identification occurred over a 6 month period. Some cases may have been missed as they were originally not marked as being a cause of death fitting the research criteria, with their true nature only becoming evident after autopsy. As this was a prospective study, there was no means of predicting the case load, and the final case total amounted to 55 cases.

2.3 Materials

Four pieces of equipment were tested in this study. The first was a torch, the LED Lenser M7. The torch makes use of “High End Power LED”s and is 137mm long and weighs 193g. It produces 220 Lumens and operates on 4 AAA batteries. It has a burning life of 11 hours and a beam range of 255m. It comes with a lanyard for the wrist and a convenient belt clip. The torch was purchased at New World, Menlyn, Pretoria for R499,00.

Figure 1. The LED Lenser M7 torch.[158]

A magnifying lamp was also tested (model number MLPF8066-1BHC). It has a 125mm diameter, 8,3 dioptre glass lens allowing for x3 magnification. The arm length is 410mm and the entire unit attaches to a desktop by means of a clamp system. It operates from a 220V mains supply and has a fluorescent ring light surrounding the lens. It was purchased from Communica in Pretoria for R461,95.

Figure 2. The magnifying lamp.[159]

A digital microscope was also used: the Veho VMS-004 USB Microscope. It has dimensions of 125mm x 33m, with a 1.3 Mega Pixel image sensor and still- and video-capture capabilities. It has a manual focus range from 10mm to 500mm and a magnification ratio of 20x and 400x. Videos are saved in AVI format, while photos are JPEG or BMP. Illumination is provided by an 8 LED light source which can be adjusted by a control wheel. The microscope is powered via the USB port in a computer. Microcapture software is included which allows approximate measurements to be calculated on the images. It was purchased from The Gadget Shop in Brooklyn Mall, Pretoria for R1199,00.

Figure 3. The VMS-004 USB digital microscope.[160]

A forensic light source was also procured on indefinite loan from the SAPS. The unit used is a Polilight® PL500 from Rofin Australia PTY. LTD. It is a 500 Watt high-intensity Xenon light source with dimensions of 33x15x37cm and weighing 9.9kg. It uses a 2m long flexible liquid light guide and 12 selectable and tuneable filters to generate light of varying wavelengths; namely UV, 415nm, 450nm, 470nm, 490nm, 505nm, 530nm, 555nm, 590nm, 620nm, 650nm and IR. It uses a standard power supply ranging from 90-260 volts and 50-60Hz. Four pairs of goggles (clear, red, orange and yellow) accompany the unit for the user's protection. Light yellow, yellow, orange and red camera filters are also provided to allow documentation of findings. The PL500 retails for R395 000,00 excluding VAT, based on an exchange rate of US$1=R8,50 (as on 2 January 2013).

Figure 4. The PL500 Polilight®.[161]

A Canon EOS 450D single-lens reflex digital camera with built-in flash was borrowed from a fellow student to document significant findings. It saves images in JPEG format to an SD memory card. The camera was set on automatic settings except for photographing images illuminated with the Polilight®. In these cases, the camera was fitted with the orange filter provided in the Polilight® kit, set to manual with the shutter speed at 2.5 seconds and the aperture set to full to let in the most light possible.

2.4 Methodology

The case victims were viewed by the attending pathologist and then subsequently undressed by the attending prosector. The prosectors were asked to be as careful as possible when removing clothing. The bodies were not washed or cleaned in any way before this study's examination in order to preserve as much adherent evidence as possible. This also meant however, that blood may have obscured other evidence, and the violent nature of the cases studied meant that often a lot of blood had been expelled from the body via the wounds.

With the permission of the pathologist, the body was then moved to an adjacent room for examination purposes. The clothes were also laid out on a workbench in the room for inspection.

The bodies and clothing of the individuals were examined first using the torch, then the magnifying light, then the digital microscope, and lastly, the Polilight®. This ordering was intended to go from perceived weakest – and therefore least likely to detect evidence – to strongest, to try and eliminate the bias of seeking out already-found evidence. The digital microscope was used at 20x magnification and was connected to an HP ProBook 4515s laptop using Windows 7 Home Basic. The Polilight® was set at 450nm (recommended for general searching in the instruction booklet) at full power (P8) (to maximize the chance of discovering evidence) in conjunction with orange filter goggles. Equipment was used as per the accompanying instruction manuals, as part of the aim of this study was to find equipment which does not require specialist training and can be used by the average police officer, thereby increasing the likelihood of its application.

The anterior aspect of the body was examined first, at which point the body was turned over and the posterior aspect was examined. Evidence that was discovered was noted. This included, but was not limited to, bloodstains, fingerprints, biological fluids, foreign hairs and fibres, glass, paint and soil (See Appendix C). Interesting findings or representative examples were photographed.

The attending pathologist was informed of the evidence discovered through the examinations and it was left to their discretion whether or not to collect samples. Because the collection of samples and further confirmatory testing was beyond the scope of the study, evidence found could only be given assumptive descriptions and may not have been their true identities (for example, a sample may have been described as semen but this was decided on the location of the fluid and the nature of the case).

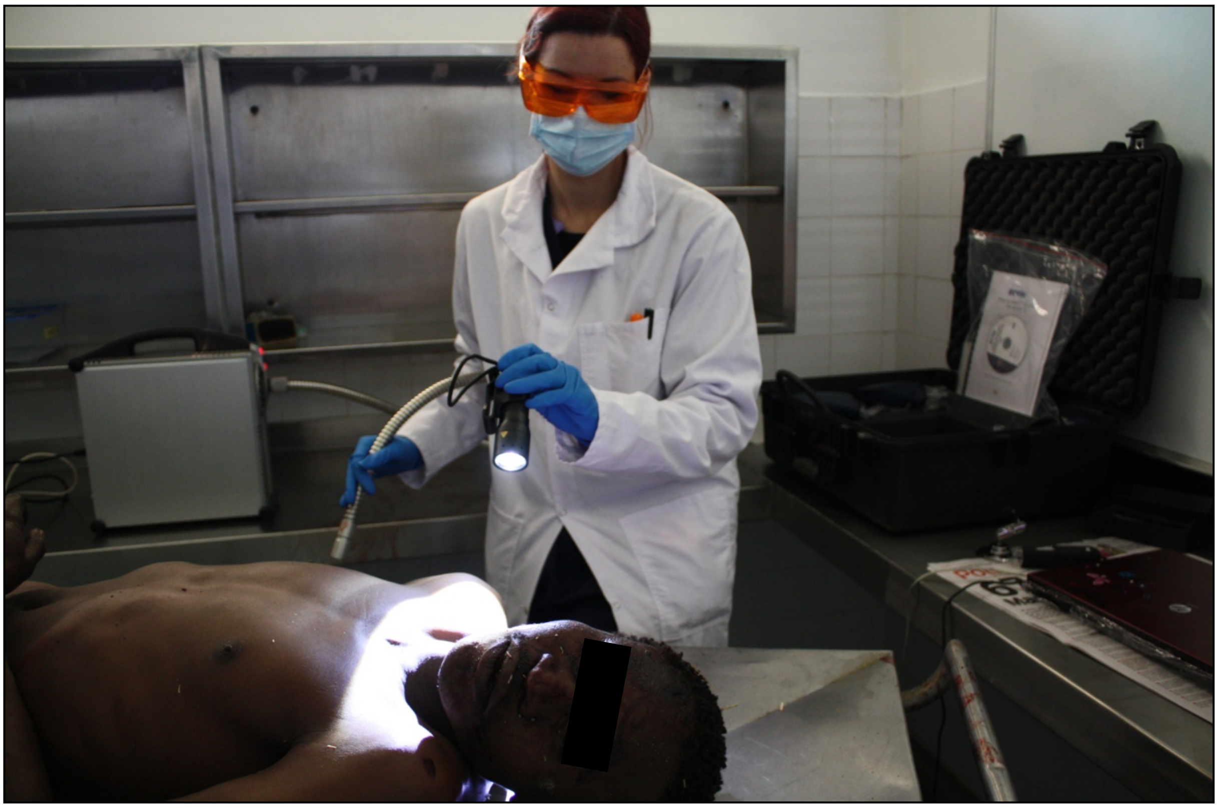

Figure 5. Use of the torch.

Figure 6. Use of the digital microscope.

Figure 7. Use of the digital microscope.

Figure 8. Use of the magnifying lamp.

Figure 9. Use of the Polilight®.

The different imaging technologies were compared as to their cost, evidence detection ability, ease of use and required time investment.

Following the examination stage of the study, feedback was sought from magistrates, senior investigators, prosecutors, pathologists, and any other significant role players, by means of a short structured questionnaire regarding the usefulness of evidence recovery to judicial proceedings. An explanatory introduction with regards to the scope of the study was included to ensure standardization of understanding (See Appendix D).

Assistance with statistical analysis was sought from the Statistics Department at the University of Pretoria. The IBM SPSS Statistics Version 21® program was used for the statistical analysis. As it was not a strongly quantitative study, only simple frequencies and comparisons were performed.

Chapter 3: Results

3.1 Study Population

A total of 55 cases were examined over a 6 month data collection period. Out of the 55 selected cases fitting the inclusion criteria, 8 (14.5%) were PVAs, 14 (25.5%) were victims of blunt force assault, 21 (38.2%) were victims of sharp force assault, 3 (5.5%) were victims of manual strangulation, 1 (1.8%) was a victim of ligature strangulation, 1 (1.8%) victim was gagged, 6 (10.9%) victims succumbed to multiple forms of trauma and 1 (1.8%) victim succumbed to other forms of trauma (a cyclist hit by a car).

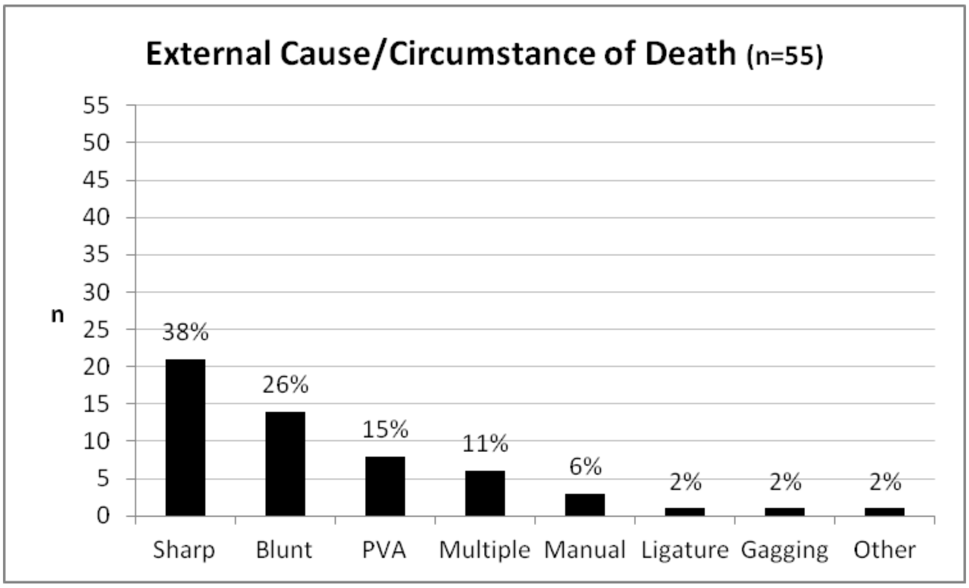

Figure 10. External cause/circumstance of death for the study population.

3.1.1 Sex

Forty-three (78.2%) victims were male and 12 (21.8%) victims were female. The torch and magnifying lamp performed better for males than females, whereas the digital microscope and Polilight® performed better on females. The difference in evidence detection between the genders was not found to be significant.

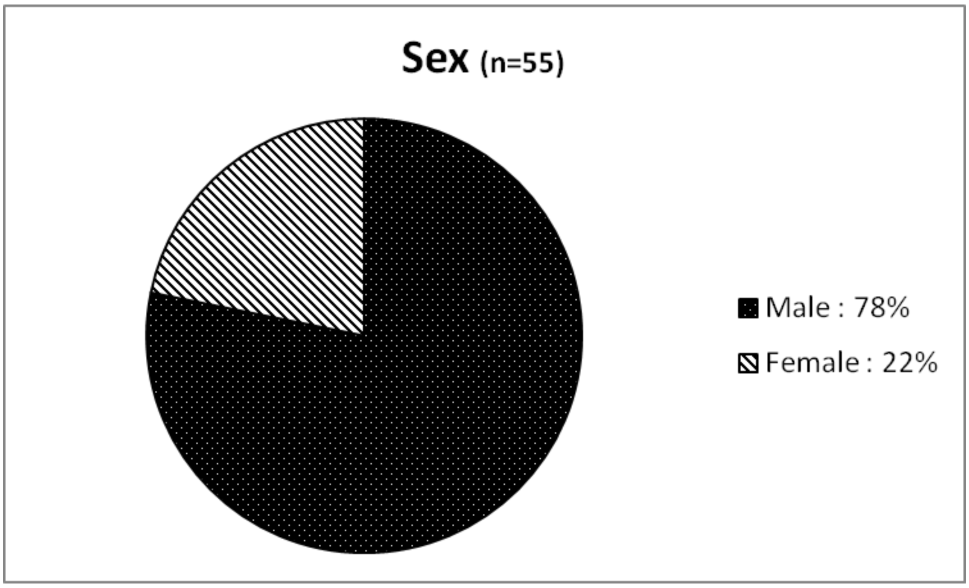

Figure 11. Gender distribution of the study population.

3.1.2 Race

Seven (12.7%) victims were White, 46 (83.6%) victims were Black and 2 (3.6%) victims were Coloured. Race was found to not be significantly associated with the increased or decreased detectability of any particular evidence types, or to all evidence in general.

According to the Kruskal-Wallis test,[162] the torch performed best on Black victims, 2nd best on White victims and worst on Coloured victims. The magnifying lamp performed best on Black victims, 2nd best on Coloured victims and worst on white victims. The digital microscope performed best on Black victims, 2nd best on Coloured victims and worst on White victims. The Polilight® performed best on Black victims, 2nd best on White victims and worst on Coloured victims. Taken together, performance was best on Black victims, then Coloured victims, then White victims. None of these differences were found to be significant.

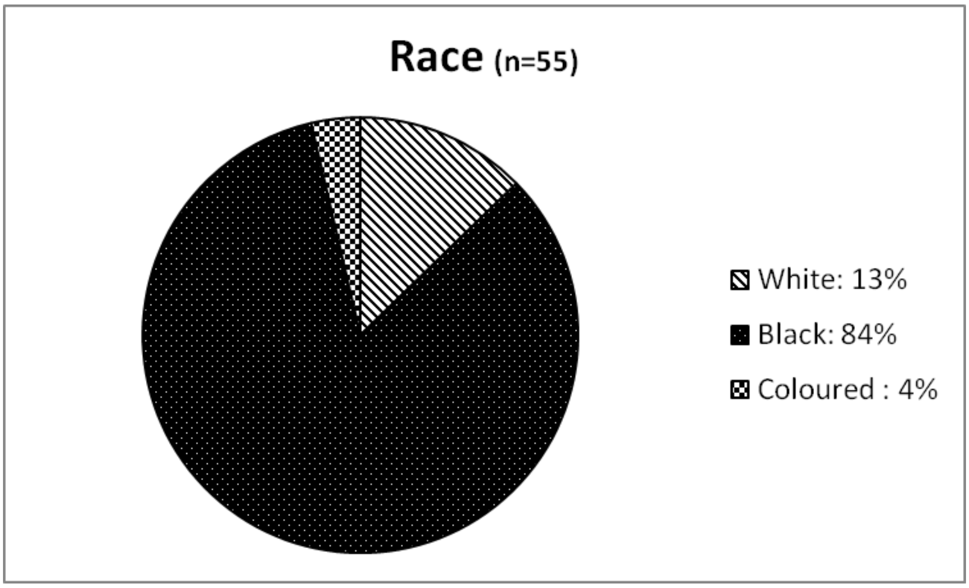

Figure 12. Racial distribution of the study population.

3.1.3 Rape/Sexual Assault[c]

Seven (12.7%) cases were suspected to include an element of rape or sexual assault. Victims suspected of being raped were all female (n=7). This was highly significant (p=0.00).

14.3% of White victims were suspected of being raped (n=7). 13.0% of Black victims were suspected of being raped (n=46). No Coloured victims were suspected of being raped (n=2). None of these associations proved statistically significant (p<0.05). There was also no statistically significant association between the detection of fluids and cases of suspected rape/sexual assault.

All of the manual strangulation deaths were suspected to involve the element of rape or sexual assault (n=3). The ligature strangulation and gagging cases were also rape-suspected cases. One third (33.3%) of the multiple-methods cases were suspected of involving an element of rape (n=6). None of the other causes of death were associated with rape being suspected. The association of cause of death with rape being suspected was significant (p=0.00).

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[c] As defined in the Criminal Law (Sexual Offences And Related Matters) Amendment Act No 32 of 2007 :

- "Any person (''A'') who unlawfully and intentionally commits an act of sexual penetration with a complainant (''B''), without the consent of B, is guilty of the offence of rape."
- "A person (''A'') who unlawfully and intentionally sexually violates a complainant (''B''), without the consent of B, is guilty of the offence of sexual assault."

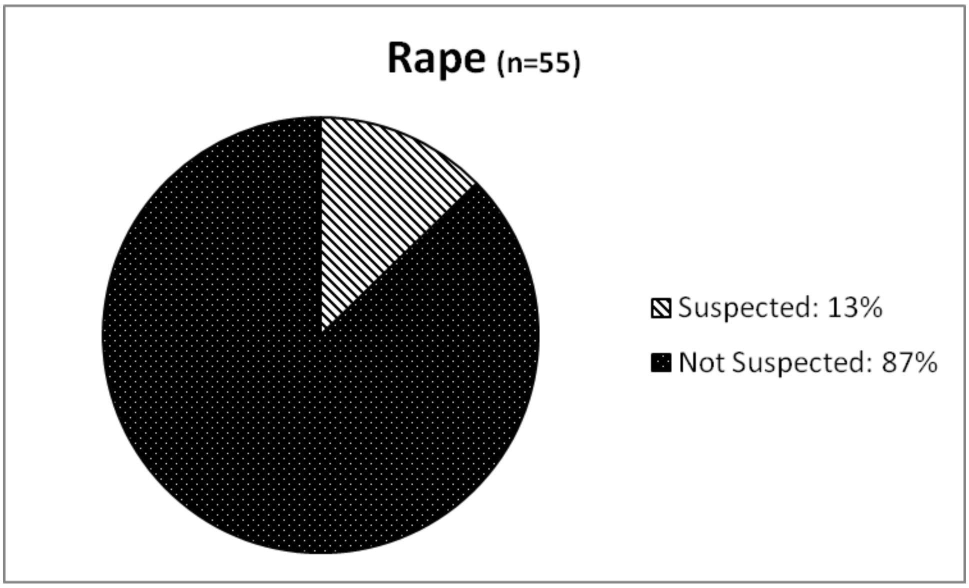

Figure 13. Cases where rape or sexual assault was suspected to have been an element.

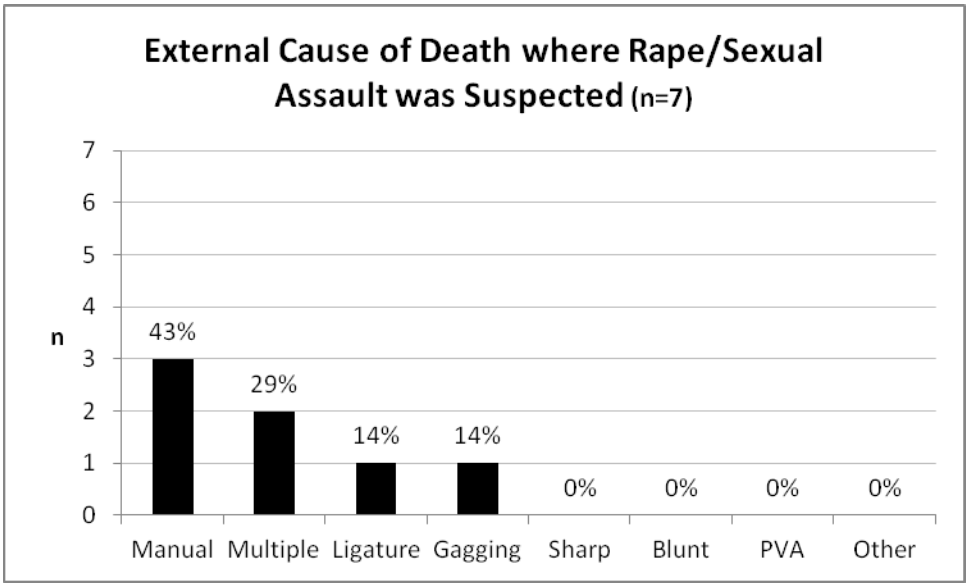

Figure 14. External cause of death for cases suspected to include an element of rape or sexual assault.

3.1.4 Blankets[d]

Four (7.3%) bodies arrived wrapped in blankets. It was found that there was no statistically significant association between a victim arriving wrapped in a blanket and the detection of fibres/hairs on the body.

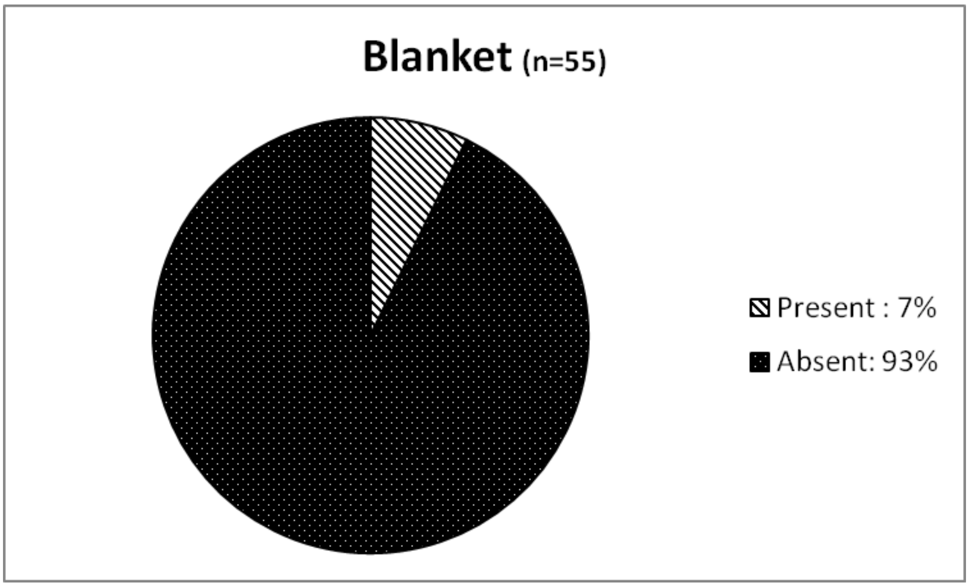

Figure 15. Cases where a victim arrived at the mortuary wrapped in a blanket.

[d] It is sometimes practice for a body to be wrapped up and carried from the scene of death in the surrounding bedclothes.

3.2 Clothing Discrepancies

According to the pathologists, no (0%) victims were wearing hats, none (0%) were wearing a coat, 49 (89.1%) were wearing a shirt, 15 (27.3%) were wearing jerseys, 46 (83.6%) were wearing pants, 6 (10.9%) were wearing shorts, 4 (7.3%) were wearing a skirt, 29 (52.7%) were wearing underwear, 6 (10.9%) were wearing a bra, none (0%) were wearing gloves, 18 (32.7%) were wearing a belt, 25 (45.5%) were wearing socks, 20 (36.4%) were wearing shoes, 16 (29.1%) were wearing a jacket, and 7 (12.7%) were wearing other items of clothing such as scarves.

According to the researcher's examination, 1 (1.8%) victim was wearing a hat, 1 (1.8%) was wearing a coat, 45 (81.8%) were wearing a shirt, 16 (29.1%) were wearing a jersey, 45 (81.8%) were wearing pants, 4 (7.3%) were wearing shorts, 3 (5.5%) were wearing a skirt, 35 (63.6%) were wearing underwear, 7 (12.7%) were wearing a bra, 1 (1.8%) was wearing gloves, 20 (36.4%) were wearing a belt, 35 (63.6%) were wearing socks, 24 (43.6%) were wearing shoes, 13 (23.6%) were wearing a jacket, and 9 (16.4%) were wearing other items of clothing.

Only the difference in the recording of the presence of socks was statistically significant ($p=0.013$).

Clothing Noted During Examination		
Clothing	**Pathologist**	**Researcher**
Hat	0	1
Coat	0	1
Shirt	49	45
Jersey	15	16
Pants	46	45
Shorts	6	4
Skirt	4	3
Underwear	29	35
Bra	6	7
Gloves	0	1
Belt	18	20
*Socks**	25	35
Shoes	20	24
Jacket	16	13
Other	7	9

Table 1. Discrepancies between clothing noted by pathologist and researcher.

*** = Statistically significant (p=0.013).**

3.3 Evidence Detection

Evidence noted in the subsequent pathologists' reports was taken as naked-eye observations for comparative purposes, with the hopes of minimizing some of the bias produced by a lone examiner.

The minimum that any of the technologies detected was 0 evidence types. The maximum that the attending pathologist noted for any one case was 3 evidence types. The maximum that use of the torch, magnifying lamp and Polilight® could each detect on any given body was 7 evidence categories. Use of the digital microscope was able to detect a maximum of 9 evidence categories on any given body. With all the techniques combined, the minimum evidence categories detected was 0 and up to a maximum of 10 different evidence types. On average per body, the pathologist noted a mean of 0.85 evidence types, use of the torch detected a mean of 2.49 evidence types, use of the magnifying lamp detected a mean of 2.6 evidence types, use of the digital microscope detected a mean of 2.78 and use of the Polilight® detected a mean of 2.05 evidence types. When all the techniques were considered together, a mean of 3.96 evidence types were detected per body.

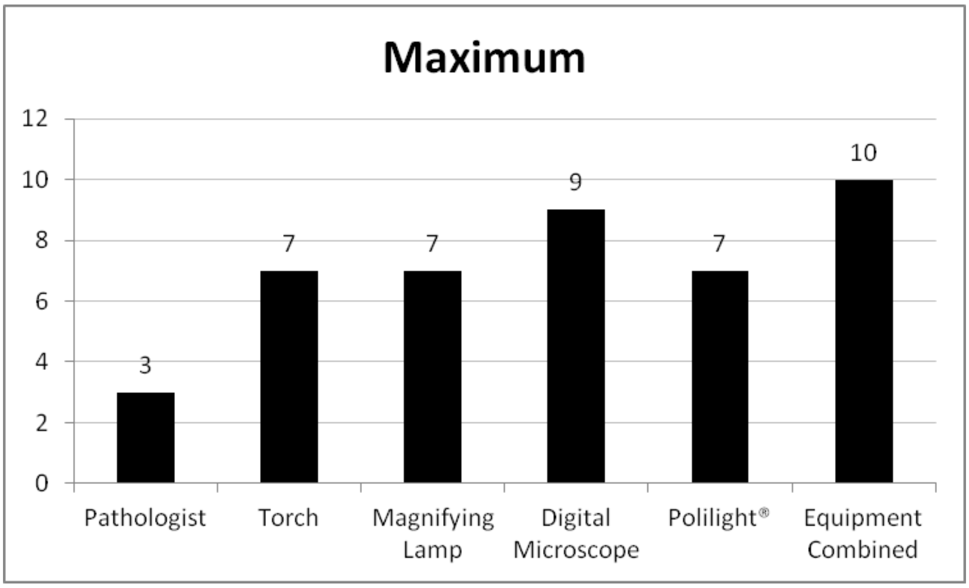

Figure 16. Maximum evidence types detected for any one case by each tool.

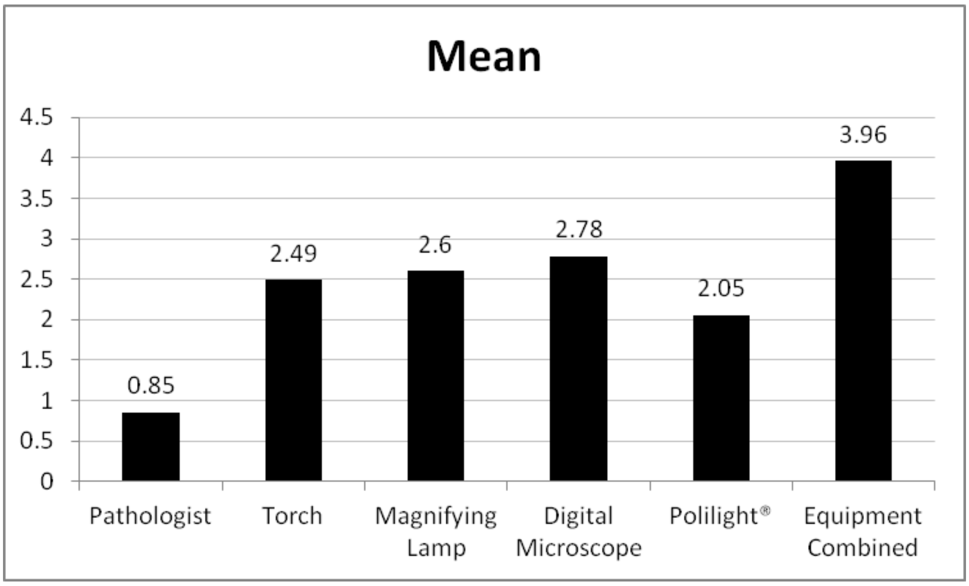

Figure 17. Mean number of evidence types detected by each tool on average.

3.3.1 Botanical Samples

Botanical samples (grass, leaves, seeds, etc.) were found on 32 out of 55 bodies (58.2%). The pathologists noted plant matter in their reports in 12 (21.8%) cases. Botanical samples were found on 27 (49.1%) of the victims by means of the torch. Botanical samples were found on 29 (52.7%) victims by means of the magnifying lamp. Plant matter was located on 31 (56.4%) of the victims by means of the digital microscope. Botanical samples were found on 8 (14.5%) victims by means of the Polilight®.

The difference between the pathologists' naked-eye examination and the number of cases where botanical samples were found by means of the evidence detection equipment was found to be statistically significant (p=0.00). The difference between the botanical samples detected by means of the Polilight® and all plant matter detected was also statistically significant (p=0.00).

The difference between plant matter noted by the pathologist and plant matter detected by means of the torch was statistically significant (p=0.001). The differences between the pathologist and the magnifying lamp (p=0.00), and the pathologist and the digital microscope (p=0.00) for plant matter detection were also statistically significant.

Use of the magnifying light was able to detect botanical samples in 2 instances more than the torch. No botanical samples were detected by means of the torch that were not detected by means of the magnifying lamp. Use of the digital microscope was able to detect botanical samples in 4 instances more than the torch, with use of the torch not being able to detect any botanical samples that use of the digital microscope could not. Use of the Polilight® was only able to detect botanical samples in 1 instance where use of the torch did not, but use of the torch was able to detect botanical samples in 20 instances that use of the Polilight® could not. In 3 instances, use of the digital microscope was able to detect botanical samples that use of the magnifying lamp did not, and in 1 instance use of the magnifying lamp was able to detect botanical samples not seen by use of the digital microscope. In only 1 instance was use of the Polilight® able to detect botanical samples not seen with use of the magnifying lamp, but the magnifying lamp out-performed the Polilight® in botanical sample detection in 22 cases. Use of the Polilight® was not able to detect any botanical samples not seen by means of the digital microscope, but use of the digital microscope managed to detect botanical samples in 23 cases more than use of the Polilight®.

The difference between the ability of the torch to detect botanical samples and the Polilight®'s ability to detect botanical samples was significant (p=0.001). The difference between the ability of the magnifying light to detect botanical samples and the Polilight®'s ability to detect botanical samples was significant (p=0.00). The difference in the ability of the digital microscope to detect botanical samples and the Polilight®'s ability to detect botanical samples was significant (p=0.00). There was no significant difference between the torch and the magnifying light's abilities to detect botanical samples, or the torch and digital microscope's abilities to detect botanical samples, or the magnifying light and digital microscope's abilities to detect botanical samples.

If these techniques were to be used in combination with one another, the combination of the magnifying lamp and the digital microscope would detect the most botanical samples, closely followed by the combination of the digital microscope and the Polilight®. The use of the torch along with the Polilight® would be the least effective for botanical sample detection.

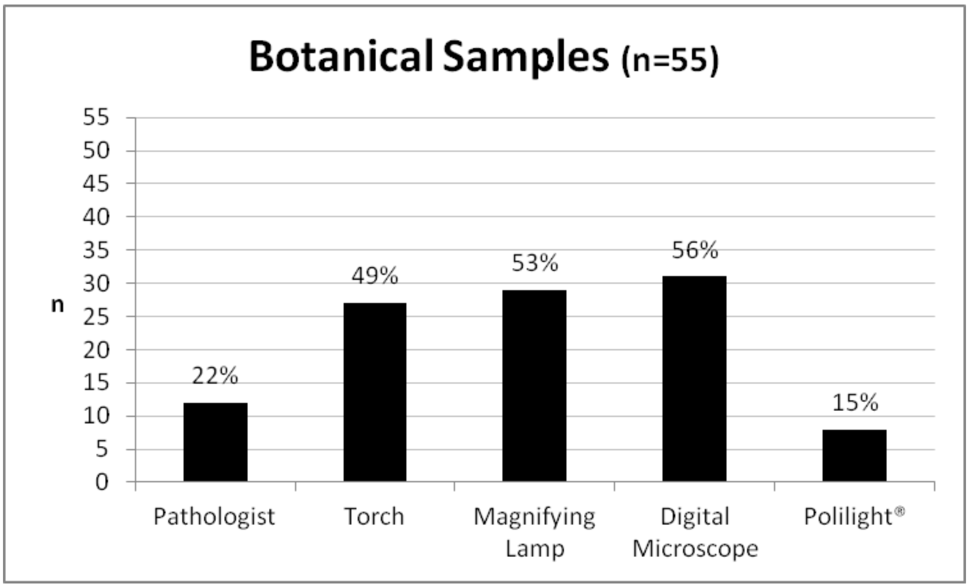

Figure 18. Comparison of botanical sample detection.

3.3.2 Geological Samples

Geological samples (gravel, sand, dirt, etc.) were found on 34 out of 55 bodies (61.8%). Ground matter was noted in the pathologists' reports in 17 (30.9%) cases. Geological samples were found on 27 (49.1%) of the victims by means of the torch. Geological samples were found on 30 (54.5%) of the victims by means of the magnifying lamp. Ground matter was found on 33 (60.0%) of the victims by means of the digital microscope. Geological samples were detected on 4 (7.3%) victims by means of the Polilight®.

The difference between the pathologists' detection of ground matter and ground matter found by all the tools was statistically significant (p=0.00). The difference between the geological samples found by all the tools and those found just by the torch was statistically significant (p=0.016). The same applies for the Polilight® (p=0.00).

The difference between the pathologist and the torch in geological sample detection was slightly statistically significant (0=0.031). The differences between ground matter detection by the pathologist and the magnifying lamp (p= 0.007), and between the pathologist and digital microscope (p=0.002), and the pathologist and the Polilight® (p=0.001) were statistically significant.

In 3 instances use of the magnifying lamp was able to detect geological samples that the torch could not, and in no instances was use of the torch able to detect geological samples that use of the magnifying lamp could not. Similarly, use of the digital microscope was able to detect geological samples in 6 instances where use of the torch did not, and use of the torch was not able to detect any geological samples that use of the digital microscope could not. In only 1 case was use of the Polilight® able to detect ground matter that use of the torch did not, but in 24 cases the use of the torch was able to detect geological samples not detected by use of the Polilight®. Use of the digital microscope was able to detect geological samples in 3 cases where use of the magnifying lamp could not, whereas use of the magnifying lamp was not able to detect geological samples in any cases that use of the digital microscope could not. Use of the magnifying lamp was able to detect geological samples in 27 cases that use of the Polilight® did not, but use of the Polilight® was able to detect geological samples in only 1 case that use of the magnifying lamp did not. Similarly, use of the digital microscope was able to detect geological samples in 30 cases more than use of the Polilight®, whereas the use of the Polilight® was able to detect geological samples in only 1 case that use of the digital microscope did not.

The differences in ability of the torch and the digital microscope (p=0.031), and the torch and the Polilight® (p=0.031) to detect geological samples were slightly significant. The differences in ability of the magnifying lamp and the Polilight® (p=0.007), and the digital microscope and the Polilight® (p=0.002) to detect geological samples were highly significant.

The combined use of the digital microscope and the Polilight® would result in the detection of the most geological samples. This is closely followed by the combination of the magnifying lamp with the digital microscope, and the torch and the digital microscope. The combined use of the torch with the Polilight® would be the least effective for geological sample detection.

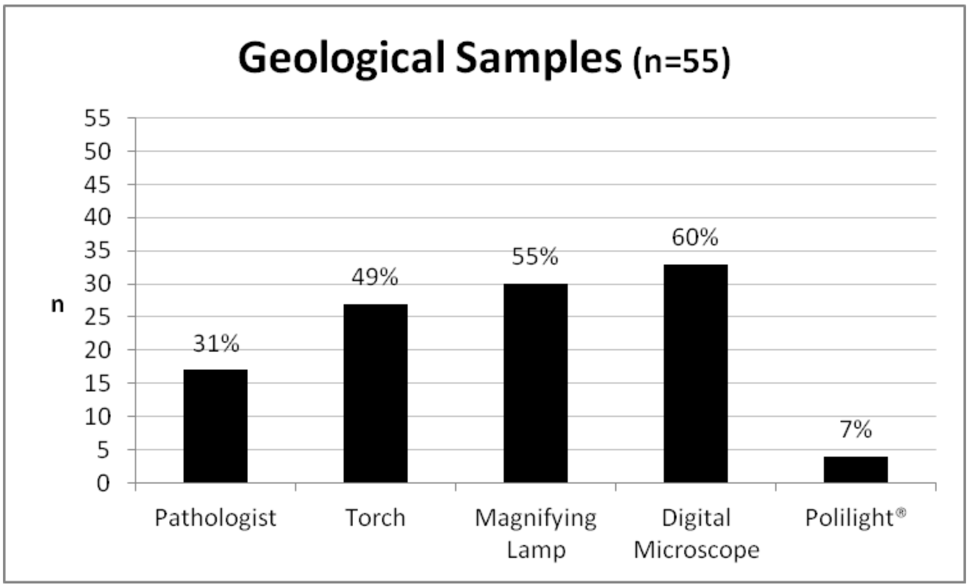

Figure 19. Comparison of geological sample detection.

3.3.3 Entomological Samples

Entomological samples (insects, maggots, etc.) were found on 3 out of the 55 bodies (5.5%). Pathologists mentioned entomological samples in 2 (3.6%) cases. Entomological samples were found on 2 (3.6%) of the victims by means of the torch, on 2 (3.6%) victims by means of the magnifying lamp, on 3 (5.5%) victims by means of the digital microscope and on 1 (1.8%) victim by means of the Polilight®.

Use of the magnifying lamp and the torch were not able to detect entomological samples in any instances that the other could not. Use of the digital microscope was able to detect entomological samples in 1 case that both use of the torch and use of the magnifying lamp did not, but neither use of the torch nor the magnifying lamp were able to detect entomological samples in any cases that use of the digital microscope did not. Both the use of the torch and the magnifying lamp were able to detect entomological samples in 1 instance use of the Polilight® did not, whereas use of the Polilight® was not able to detect entomological samples in any instances that use of the torch or magnifying lamp did not. Use of the digital microscope was able to detect entomological samples in 2 cases use of the Polilight® did not, whereas use of the Polilight® was not able to detect entomological samples in any cases use of the digital microscope did not. None of these differences in entomological sample detection were statistically significant.

Combining the digital microscope and the Polilight®, the magnifying lamp and the digital microscope, or the torch and the digital microscope would all be effective in detecting entomological samples. All other combinations would be less effective. This is to be expected as the digital microscope found all the entomological samples, so any combination with this tool would be the most effective.

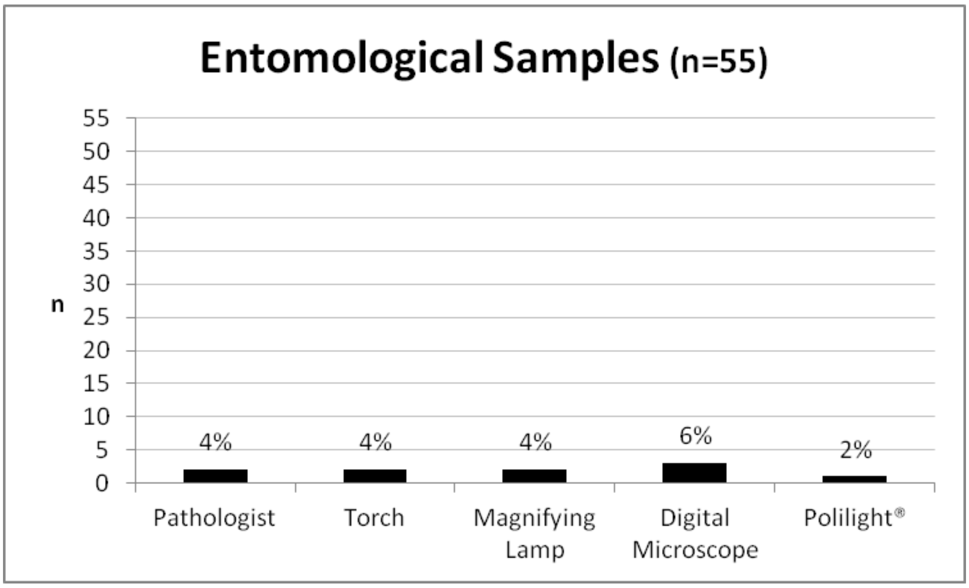

Figure 20. Comparison of entomological sample detection.

3.3.4 Glass

Glass was found on 9 out of 55 bodies (16.4%). Glass was mentioned in 1 (1.8%) pathologist's report. Glass was found on 5 (9.1%) of the victims by means of the torch. Glass was found on 9 (16.4%) victims by means of the magnifying light. Glass was found on 8 (14.5%) victims by means of the digital microscope. Use of the Polilight® resulted in the detection of glass on 1 (1.8%) victim. Of the 8 PVA cases, glass was found on 5 (62.5%) of them.

The difference between glass detection by all the tools and the pathologists' naked-eye view was statistically significant (p=0.021). Use of the Polilight®'s detection of glass compared to all the cases where glass was found was statistically significant (p=0.008). The differences between glass detection by the pathologist and the magnifying lamp (p=0.021), and between the pathologist and digital microscope were slightly significant (p=0.039).

Use of the magnifying lamp was able to detect glass in 4 instances where use of the torch did not, but use of the torch was not able to detect glass in any instances that use of the magnifying lamp did not. Similarly, use of the digital microscope was able to detect glass in 3 cases more than use of the torch, but use of the torch was not able to detect glass in any cases more than use of the digital microscope. Use of the Polilight® was not able to detect glass in any case that use of the torch did not, whereas use of the torch was able to detect glass in 4 cases that use of the Polilight® did not. Use of the magnifying lamp was able to detect glass in only 1 more case than use of the digital microscope, and use of the digital microscope was not able to detect glass in any cases where use of the magnifying lamp did not. Use of the Polilight® was not able to detect glass in any cases more than use of the magnifying lamp, but use of the magnifying lamp was able to detect glass in 8 cases more than use of the Polilight®. Similarly, use of the Polilight® was not able to detect glass in any cases more than use of the digital microscope, whereas use of the digital microscope was able to detect glass in 7 cases that use of the Polilight® did not.

The differences in ability to detect glass between the magnifying lamp and the Polilight® (p=0.021), and the digital microscope and the Polilight® (p=0.039) were significant. The other techniques performed statistically comparably for glass detection.

The combined use of the torch and the Polilight® would be the least efficient for glass detection; whereas the combination of the torch and magnifying lamp, the magnifying lamp and the digital microscope, or the magnifying lamp and the Polilight®, would all prove equally efficient in detecting glass.

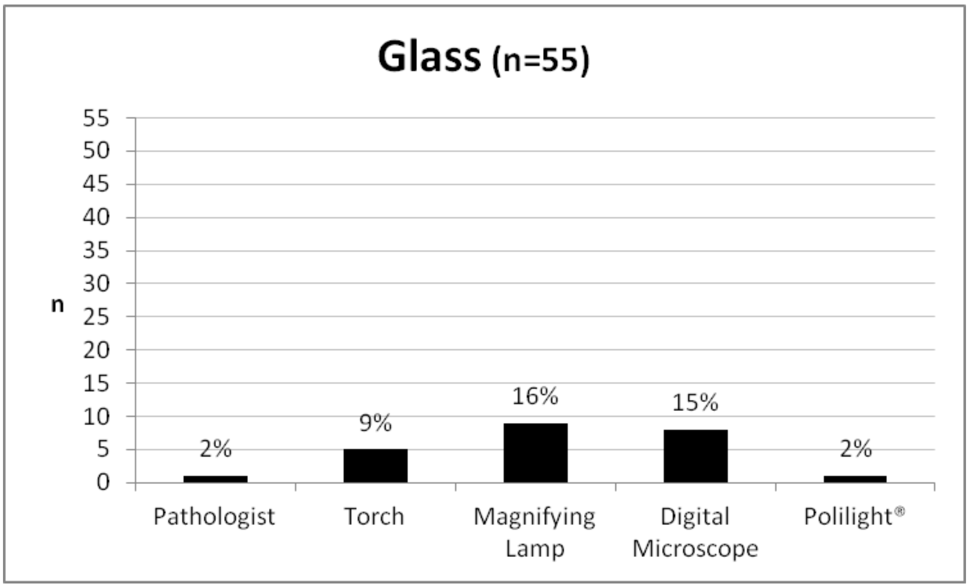

Figure 21. Comparison of glass detection.

3.3.5 Plastic

Plastic was found on 5 out of the 55 bodies (9.1%). No (0%) pathologist noted the presence of plastic in their reports. Plastic was found on 3 (5.5%) of the victims by means of both the torch and the magnifying lamp. Plastic was found on 5 (9.1%) of the victims by means of the digital microscope. Plastic was found on 2 (3.6%) victims by means of the Polilight®.

Use of the torch and use of the magnifying lamp were able to detect plastic in the same number of cases. Use of the digital microscope was able to detect plastic in 2 cases more than use of the torch, whereas the torch was not able to detect plastic in any cases more than use of the digital microscope. Use of the Polilight® was not able to detect plastic in any cases use of the torch could not, whereas use of the torch was able to detect plastic in 1 case more than use of the Polilight®. Use of the digital microscope detected plastic in 2 cases more than use of the magnifying lamp, whereas use of the magnifying lamp did not detect plastic in any cases that use of the digital microscope did not. Use of the Polilight® did not detect plastic in any cases more than use of the magnifying lamp, and the magnifying lamp was able to detect plastic in only 1 case more than use of the Polilight®. Similarly, use of the Polilight® did not detect plastic in any cases more than use of the digital microscope, but use of the digital microscope detected plastic in 3 instances more than use of the Polilight®. The differences in plastic detection were not significant among any of the techniques.

The combined use of the any of the tools with the digital microscope would all be equally effective in the detection of plastic. The combined use of the magnifying lamp with the Polilight®, the torch with the Polilight®, or the torch with the magnifying lamp would be less effective for the detection of plastic.

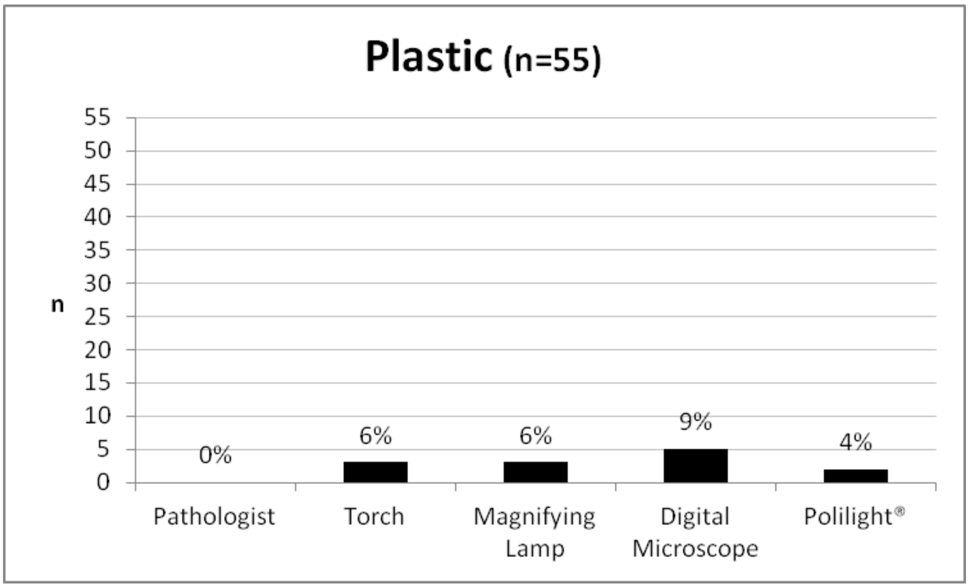

Figure 22. Comparison of plastic detection.

3.3.6 Paint

Paint smears or chips were found on 13 out of 55 bodies (23.6%). Paint was not mentioned (0%) in any of the pathologists' reports. Use of the torch and magnifying lamp were each able to find paint on 11 (20%) of the victims. Paint was found on 10 (18.2%) victims by means of the digital microscope. Use of the Polilight® found paint on 6 (10.9%) victims. Of the 8 PVA cases, paint was found on 4 of them (50.0%).

The difference between paint that was detected by any of the tools and the paint detected by use of the Polilight® was statistically significant (p=0.016).

Use of the torch and use of the magnifying light were able to detect paint for the same cases. In 1 case, the use of the torch detected paint that use of the digital microscope did not. Use of the Polilight® detected paint in 2 cases neither use of the torch nor the magnifying lamp did, whereas use of the torch and magnifying lamp detected paint in 7 cases that use of the Polilight® did not. Use of the digital microscope did not detect paint in any cases use of the magnifying lamp did not, but use of the magnifying lamp detected paint in 1 case that use of the digital microscope did not. Use of the Polilight® detected paint in 2 cases use of the digital microscope did not, whereas use of the digital microscope detected paint in 6 cases use of the Polilight® did not. None of these differences in paint detection were significant.

Combination of the torch with the Polilight® or the magnifying lamp with the Polilight® would detect the most paint, followed by the digital microscope paired with the Polilight®.

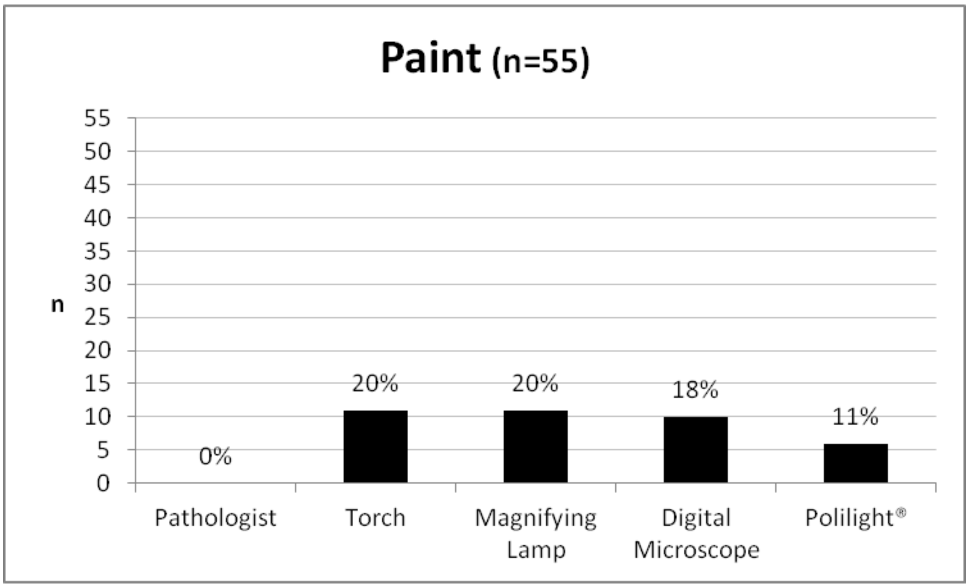

Figure 23. Comparison of paint detection.

3.3.7 Paper

Paper was found on 1 out of 55 bodies (1.8%). Paper was not found on any (0%) of the victims by the pathologist or by means of the torch, magnifying lamp or digital microscope. Paper was found on 1 (1.8%) victim by means of the Polilight®.

The use of the Polilight® detected paper in 1 instance that the torch, magnifying lamp and the digital microscope did not.

As the Polilight® was the only tool to detect paper; it makes no difference which tool is combined with it for paper detection purposes.

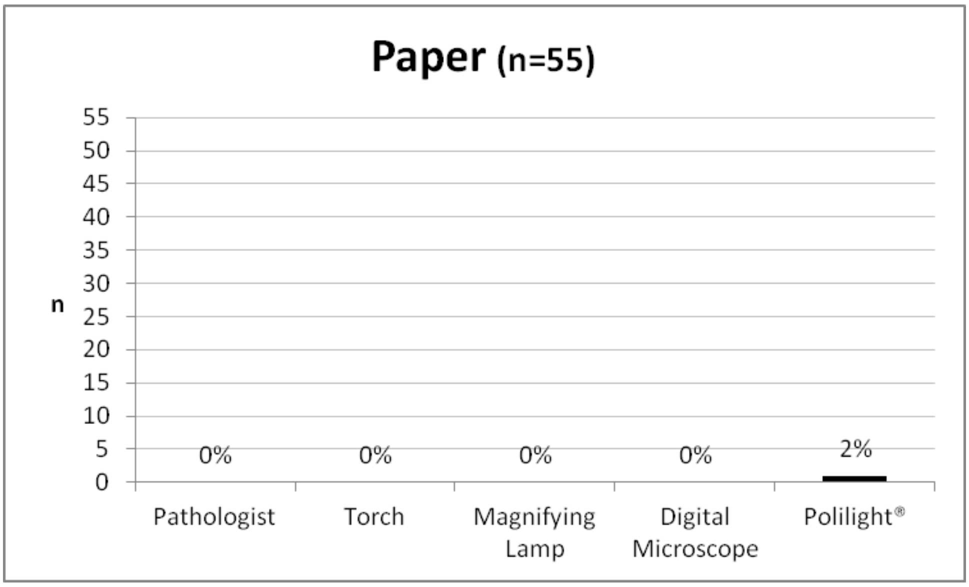

Figure 24. Comparison of paper detection.

3.3.8 Fibres/Hairs

Fibres/hairs were found on 41 out of 55 bodies (74.5%). No (0%) pathologist mentioned hairs or fibres in their reports. Fibres/hairs were found on 12 (21.8%) of the victims by means of the torch. Fibres/hairs were found on 21 (38.2%) of the victims by means of the magnifying lamp. Fibres/hairs were detected on 25 (45.5%) victims using the digital microscope. Fibres/hairs were found on 37 (67.3%) victims by means of the Polilight®. Of the 4 cases where a victim was wrapped in a blanket, fibres/hairs were detected on all of them (100.0%). This was not statistically significant, however.

The difference between all the bodies with fibres/hair present and what was detected by means of the torch was statistically significant (p=0.00). The same applies for the magnifying light (p=0.00) and digital microscope (p=0.00).

Use of the magnifying lamp was able to detect fibres/hair in 9 instances use of the torch did not, but use of the torch did not detect fibres/hair in any cases that use of the magnifying lamp did not. Use of the digital microscope detected fibres/hair in 13 cases use of the torch did not, and again, use of the torch did not detect fibres/hair in any instances that use of the digital microscope did not. Use of the Polilight® detected fibres/hair in 29 cases use of the torch did not, and use of the torch detected fibres/hair in 4 cases that use of the Polilight® did not. Use of the digital microscope detected fibres/hair in 4 cases use of the magnifying lamp did not, but use of the magnifying lamp did not detect fibres/hair in any cases that use of the digital microscope did not. Use of the Polilight® detected fibres/hair in 20 cases use of the magnifying lamp did not, and use of the magnifying lamp detected fibres/hair in 4 cases that use of the Polilight® did not. Use of the Polilight® detected fibres/hair in 16 cases that use of the digital microscope did not, whereas use of the digital microscope detected fibres/hair in 4 cases that use of the Polilight® did not.

The differences in fibre/hair detection between the torch and magnifying lamp (p=0.004), between the torch and digital microscope (p=0.00), between the torch and Polilight® (p=0.00), between the magnifying lamp and the Polilight® (p=0.002), and between the digital microscope and Polilight® (p=0.012) were significant. The difference in fibre/hair detection between the magnifying lamp and digital microscope was not significant.

Any tool combined with the Polilight® would be effective for fibre/hair detection. The least effective combination would be the torch with the magnifying lamp.

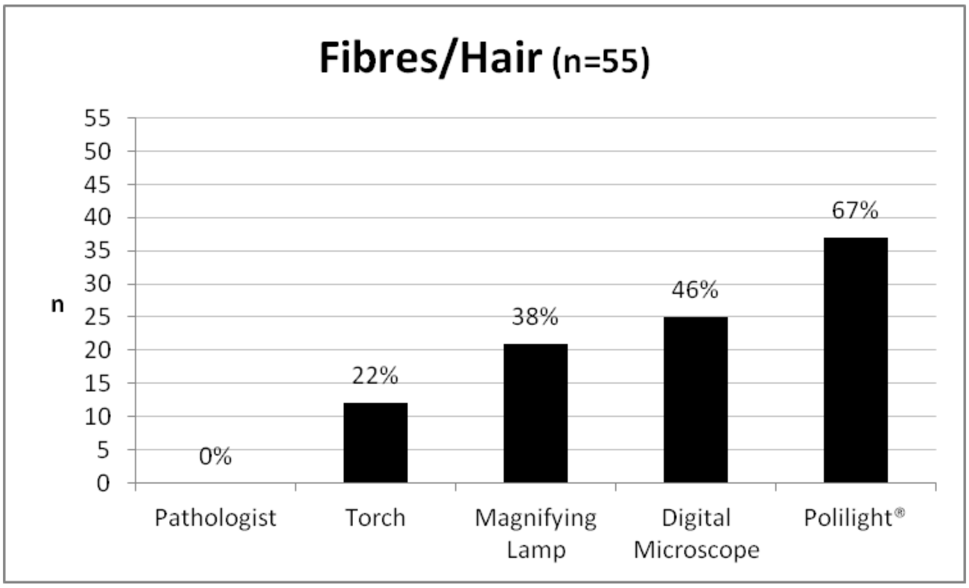

Figure 25. Comparison of fibre/hair detection.

3.3.9 Fluids

Fluid was found on 36 out of 55 bodies (65.5%). This did not include what appeared to be condensation from refrigeration. No (0%) pathologists' reports mentioned an unknown fluid in their reports. Use of the torch found fluids on 22 (40.0%) of the bodies. Fluids were found on 13 (23.6%) victims by means of the magnifying lamp. Fluid was found on 17 (30.9%) victims by means of the digital microscope. Use of the Polilight® found fluid on 26 (47.3%)

victims. Of the 7 cases where rape or sexual assault was suspected, fluids were found in 5 of them (71.4%). This was not statistically significant, however.

The difference between all the fluids detected by all the tools together and the fluids detected by means of the torch was statistically significant (p=0.00). The same applies for the magnifying lamp (p=0.00), digital microscope (p=0.00) and Polilight® (p=0.002).

Use of the magnifying lamp detected fluids in 1 case use of the torch did not, whereas use of the torch detected fluids in 11 cases that use of the magnifying lamp did not. Use of the digital microscope detected fluids in 4 cases use of the torch did not, whereas use of the torch detected fluids in 9 cases that use of the digital microscope did not. Use of the Polilight® detected fluids in 13 cases use of the torch did not, whereas use of the torch detected fluids in 9 cases that use of the Polilight® did not. Use of the digital microscope detected fluids in 4 cases that use of the magnifying lamp did not, but use of the magnifying lamp did not detect fluids in any cases that use of the digital microscope did not. Use of the Polilight® detected fluids in 15 cases that use of the magnifying lamp did not, whereas use of the magnifying lamp detected fluids in 2 cases use of the Polilight® did not. Similarly, use of the Polilight® detected fluids in 12 cases use of the digital microscope did not, whereas use of the digital microscope detected fluids in 3 cases that use of the Polilight® did not. The differences in fluid detection between the torch and magnifying lamp (p=0.022), the magnifying lamp and the Polilight® (p=0.002), and the digital microscope and the Polilight® (p=0.035) were statistically significant.

The combined use of the torch with the Polilight® would result in the most fluid detection. The digital microscope used with the magnifying lamp would result in the least fluid detected.

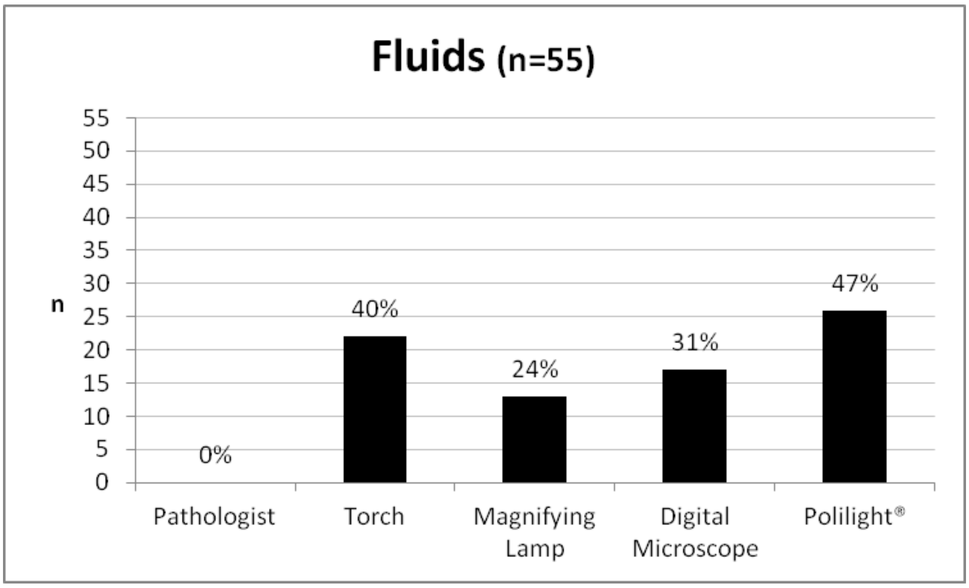

Figure 26. Comparison of fluid detection.

Figure 27. Otherwise invisible nasal and oral fluids as seen with the Polilight®.

3.3.10 Faeces

Faecal matter was found on 3 out of 55 bodies (5.5%). No (0%) pathologist mentioned the presence of faeces in their reports. Faeces was found on 2 (3.6%) of the victims by means of the torch, magnifying lamp, digital microscope and Polilight®.

Detection of faeces was comparable for the torch and magnifying lamp, torch and digital microscope, and the magnifying lamp and the digital microscope. Use of the torch and Polilight® each detected faeces in 1 case the other did not. The same applies for the magnifying lamp and the Polilight®, and the digital microscope and the Polilight®. None of these differences were statistically significant.

Combining the torch and Polilight®, the magnifying lamp and the Polilight®, or the digital microscope and the Polilight® would all prove effective for faeces detection. The combination of the magnifying lamp and the digital microscope, the torch and the magnifying lamp, or the torch and the digital microscope would all be less effective for faeces detection.

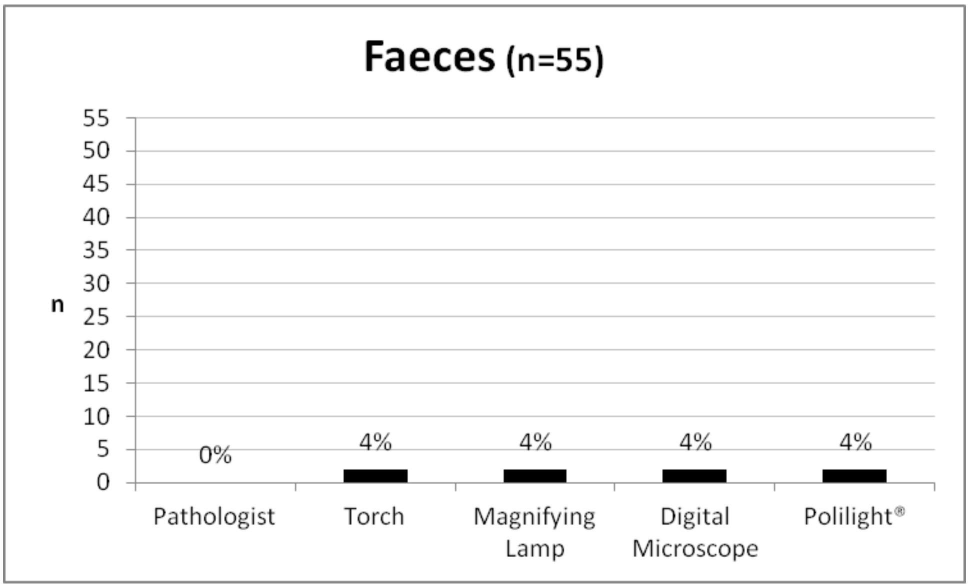

Figure 28. Comparison of faeces detection.

3.3.11 Fingerprints

Fingerprints were found on 1 out of the 55 bodies (1.8%). These were found using the torch and the magnifying lamp. The fingerprints were imperceptible using the digital microscope or the Polilight®.

Use of the torch and magnifying light detected the same number of cases with fingerprints. Use of the torch detected fingerprints in 1 case more than use of the digital microscope and Polilight®. Similarly, use of the magnifying lamp detected fingerprints in 1 more case than either use of the digital microscope or Polilight®. None of these differences in fingerprint detection were statistically significant.

Only the combined use of the digital microscope and the Polilight® would be wholly ineffective in detecting fingerprints. All other possible combinations would still uncover fingerprints. This is to be expected as fingerprints were only found in 1 case and only by using the torch and magnifying lamp.

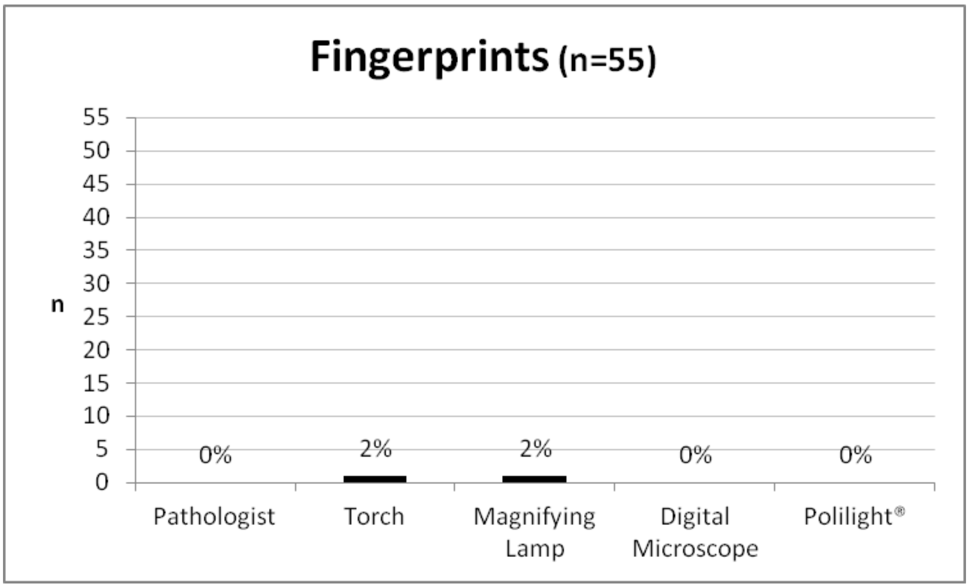

Figure 29. Comparison of fingerprint detection.

3.3.12 Other Imprints

Other imprints were found on 4 out of the 55 bodies (7.3%). One (1.8%) pathologist's report mentioned other imprints. Use of the torch found other imprints on 3 (5.5%) of the victims. Other imprints were found by means of the magnifying lamp on 1 (1.8%) victim. Use of the digital microscope found other imprints on none (0%) of the victims. Use of the Polilight® found other imprints on 1 (1.8%) victim.

Use of the torch detected other imprints in 2 cases more than use of the magnifying lamp and in 3 cases more than use of the digital microscope. Neither the use of the magnifying lamp nor digital microscope detected other imprints in any cases where use of the torch did not. Use of the Polilight® detected other imprints in 1 case that use of the torch did not, whereas use of the torch detected other imprints in 3 instances that use of the Polilight® did not. Use of the magnifying lamp and the Polilight® both detected other imprints in 1 case more than use of the digital microscope. Use of the magnifying lamp and Polilight® each detected other imprints in 1 case where the other did not. None of the differences in other imprint detection were statistically significant.

The combination of the torch and the Polilight® would offer the best chance of detecting other imprints. The combination of the magnifying lamp and the digital microscope, or the digital microscope and the Polilight®, would be the least effective for other imprint detection.

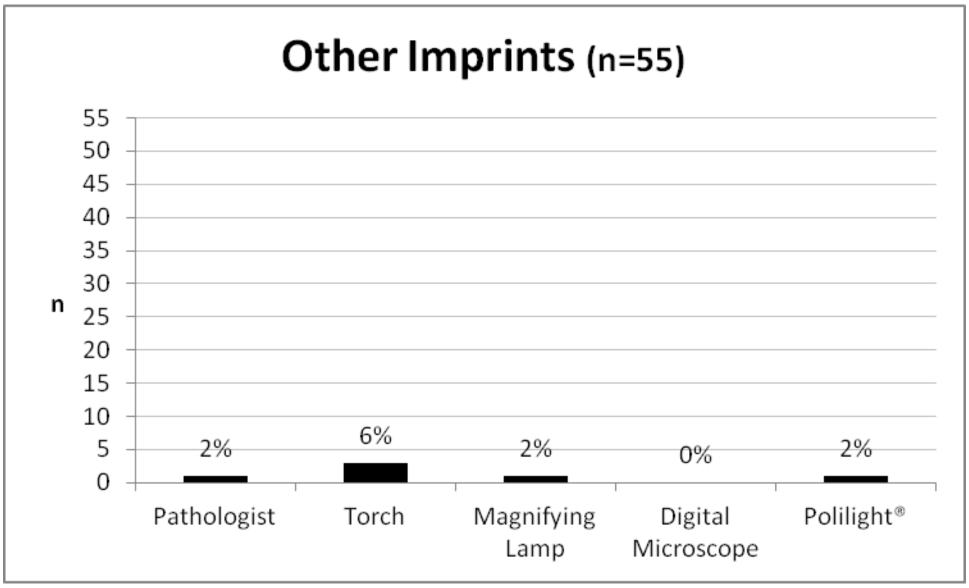

Figure 30. Comparison of other imprint detection.

3.3.13 Tattoos

Tattoos were found on 8 out of the 55 bodies (14.5%) by means of the tools. Eleven (20.0%) pathologist reports mentioned tattoos. Tattoos were found on 8 (14.5%) of the victims by means of the torch. Tattoos were found on 7 (12.7%) of the victims by means of the magnifying lamp. Tattoos were found on 6 (10.9%) of the victims by means of the digital microscope. Use of the Polilight® found tattoos on 6 (10.9%) victims.

Use of the torch detected tattoos in only 1 instance more than use of the magnifying lamp did, and use of the magnifying lamp did not detect tattoos in any instances that use of the torch did not. Similarly, the use of the torch detected tattoos in 2 cases where use of the digital microscope and Polilight® did not, and neither use of the digital microscope nor the Polilight® detected tattoos in any instances that use of the torch did not. Use of the magnifying lamp detected tattoos in 1 instance that use of the digital microscope did not and the use of the digital microscope did not detect tattoos in any instances that use of the magnifying lamp did not. Use of the magnifying lamp detected tattoos in 2 cases that use of the Polilight® did not and use of the Polilight® detected tattoos in 1 case that use of the magnifying lamp did not. Use of the digital microscope detected tattoos in 2 cases that use of the Polilight® did not, and use of the Polilight® detected tattoos in 2 instances that use of the digital microscope did not. None of these differences were found to be statistically significant.

The combination of the magnifying lamp and the digital microscope would prove the least effective in the detection of tattoos. All other possible combinations would be equally effective for tattoo detection.

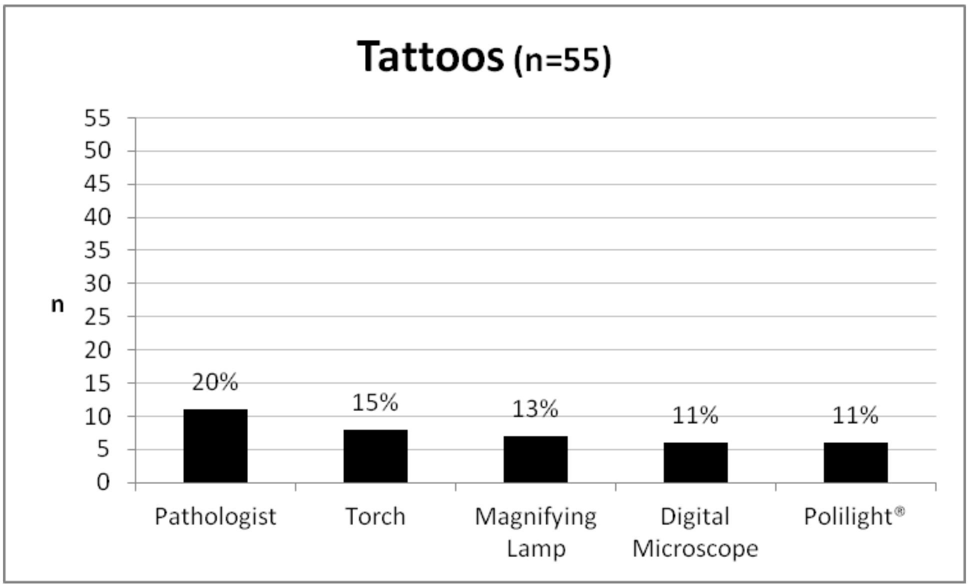

Figure 31. Comparison of tattoo detection.

3.3.14 “Red Streaks”

Indistinct areas of redness seen only by means of the Polilight® were noted on some of the bodies. There was no strict pattern as to the appearance (beside the apparent red colour) or location of these marks. The torch, magnifying lamp and digital microscope did not uncover anything corresponding to the areas where these streaks appeared and none of the pathologists mentioned anything that could be linked to this phenomenon. There is also no literature describing anything similar to this anomaly. It has been hypothesized that this phenomenon may be due to bacterial growth.[164] For purposes of further discussion, these areas of redness will be referred to as “red streaks” (See Figure 33).

“Red streaks” were found on 4 out of the 55 bodies (7.3%). The Polilight® detected “red streaks” in 4 cases that the torch, magnifying lamp and digital microscope did not.

There is no point in combining the equipment for “red streak” detection as only the Polilight® was able to detect this anomaly.

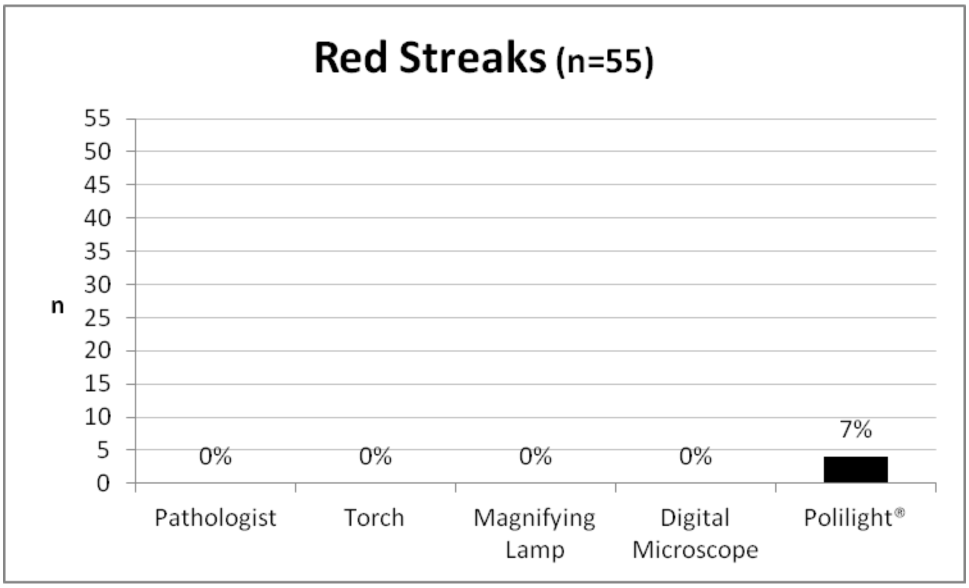

Figure 32. Comparison of "red streak" detection.

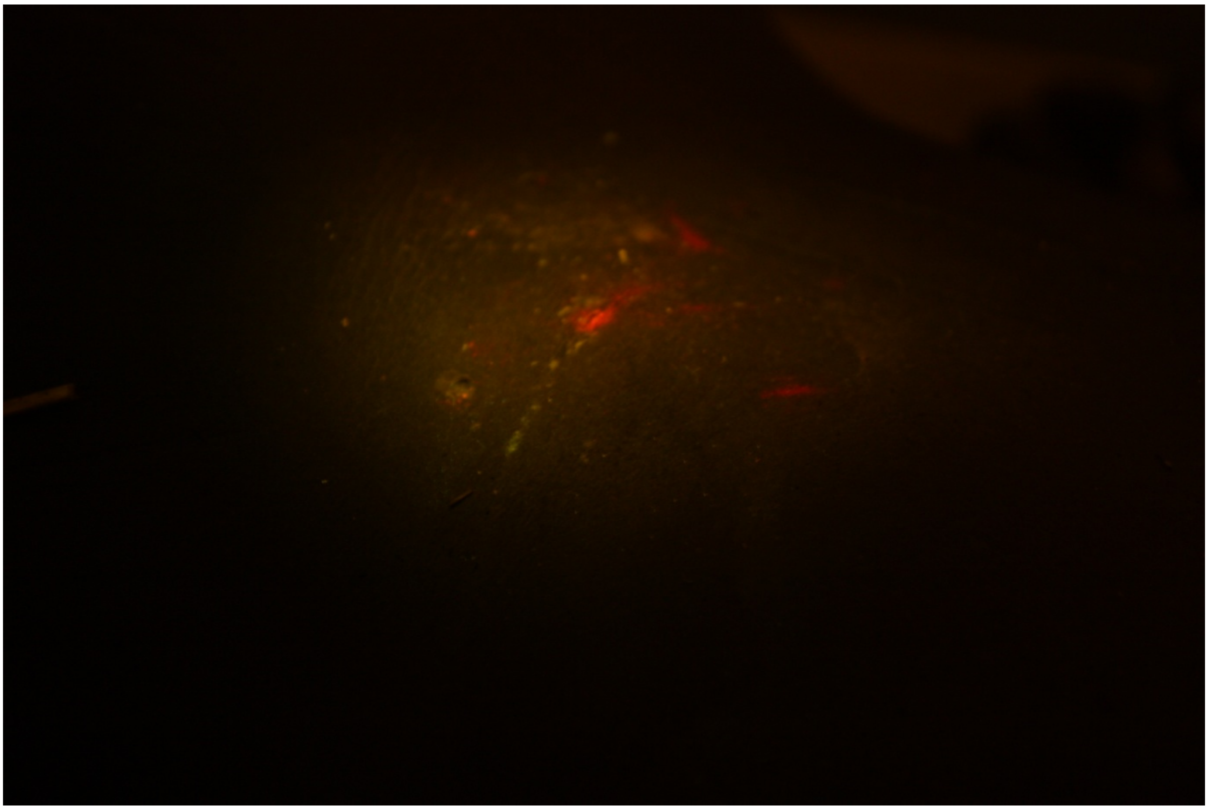

Figure 33. Example of the anomaly "red streaks" seen only under illumination with the Polilight®.

3.3.15 Other Evidence

Other evidence was found on 24 of the 55 bodies (43.6%). This included black smears, flecks, powders, a staple, gum, cigarettes, matches, stickers, mould, soot/ash etc. Three (5.5%) pathologist reports mentioned other evidence. Other evidence was found on 14 (25.5%) of the victims by means of the torch, magnifying lamp and Polilight®. Use of the digital microscope found other evidence on 13 (23.6%) victims.

The difference between the amount of other evidence detected by all the techniques and that which was noted by the pathologist was statistically significant (p=0.00). The same applies for the torch (p=0.002), magnifying lamp (p=0.002), digital microscope (p=0.001) and Polilight® (p=0.002).

The difference between the pathologists' detection of other evidence and that of the torch was statistically significant (p=0.003). The differences between the pathologist and the magnifying lamp (p=0.007), between the pathologist and the digital microscope (p=0.013), and between the pathologist and the Polilight® (p=0.003) for other evidence detection were also statistically significant.

Use of the magnifying lamp detected other evidence in 2 cases use of the torch did not, and use of the torch detected other evidence in 2 cases that use of the magnifying lamp did not. Use of the digital microscope detected other evidence in 1 instance use of the torch did not, and use of the torch detected other evidence in 2 cases that use of the digital microscope did not. Use of the Polilight® detected other evidence in 8 cases use of the torch did not, whereas use of the torch detected other evidence in 8 cases that use of the Polilight® did not. Use of the digital microscope did not detect other evidence in any cases that use of the magnifying lamp did not, but use of the magnifying lamp detected other evidence in 1 case that use of the digital microscope did not. Use of the Polilight® detected other evidence in 9 cases use of the magnifying lamp did not, and use of the magnifying lamp detected other evidence in 9 cases that use of the Polilight® did not. Use of the

Polilight® detected other evidence in 9 cases that use of the digital microscope did not, whereas use of the digital microscope detected other evidence in 8 cases that use of the Polilight® did not. None of the differences in other evidence detection were found to be significant.

The combined use of the magnifying lamp with the Polilight® would result in the most other evidence being detected. This is closely followed by the digital microscope with the Polilight® or the torch with the Polilight®. The combination of the magnifying lamp with the digital microscope would detect the least other evidence.

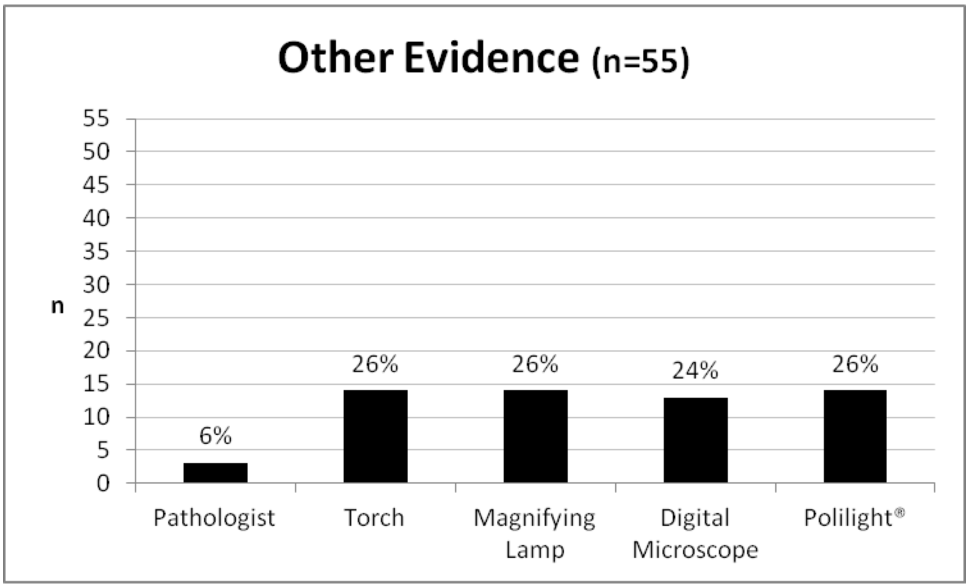

Figure 34. Comparison of other evidence detection.

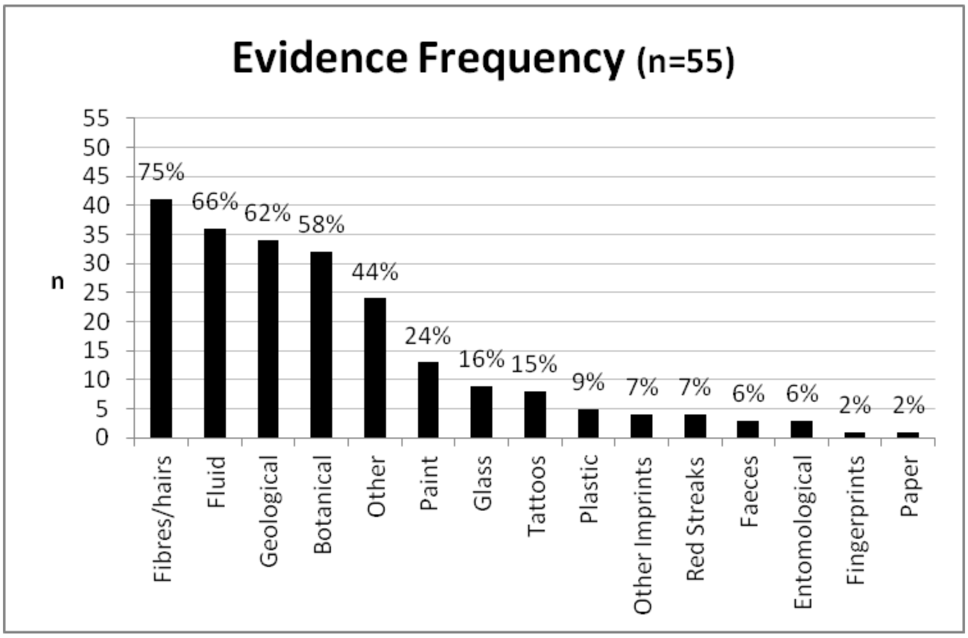

Figure 35. Evidence types from most to least common.

3.4 Equipment Comparison by Evidence Type

Evidence Type	Torch	Magnifying Lamp	Digital Microscope	Polilight®
Botanical	3rd	2nd	1st	4th
Geological	3rd	2nd	1st	4th
Glass	3rd	1st	2nd	4th
Entomological	2nd	2nd	1st	3rd
Plastic	2nd	2nd	1st	3rd
Fingerprints	1st	1st	–	–
Other Imprint	1st	2nd	–	2nd
Tattoos	1st	2nd	3rd	3rd
Faeces	1st	1st	1st	1st
"Red Streaks"	–	–	–	1st
Paper	–	–	–	1st
Fibres/hair	4th	3rd	2nd	1st
Paint	1st	1st	2nd	3rd
Fluid	2nd	4th	3rd	1st
Other Evidence	1st	1st	2nd	1st

Table 2. Comparison of overall evidence detection ability per evidence type.

– = Did not detect

3.5 Overall Performance

In terms of overall performance, “best” refers to a tool’s statistically determined ability to detect the most number of evidence types for all cases taken together. This does not refer to the amount of particles of individual evidence types that could be detected with a particular tool. Two tools may both be able to detect fibres, but one may have detected more individual fibres than the other. This difference was not taken into consideration. The true assessment of the value of the individual modalities is subjective and contentious. A tool may be sensitive but not specific, or vice versa. Also, rare phenomena may be more significant than commonly detected evidence types.

According to the Friedman Test[165] in terms of quantity of the spectrum of evidence detected, the digital microscope performed best overall. The magnifying lamp performed 2nd best, the torch performed 3rd best and the Polilight® fared the worst. This ranking of performance was found to be significant (p=0.04). On average, the Polilight® found the least evidence per case. The digital microscope found the most items per case on average, followed by the magnifying lamp, followed by the torch.

3.5.1 Combinations

The combination of the torch and the Polilight® would statistically detect the most number of evidence types. This is followed by the combination of the magnifying lamp and the Polilight®, then the digital microscope and the Polilight®, then the torch and digital microscope, and then the torch and magnifying lamp. The worst combination would be the magnifying lamp with the digital microscope. This difference in evidence detection ability amongst the various combinations was found to be statistically significant (p=0.00).

The torch combined with the magnifying lamp would detect the lowest maximum number of evidence types in any one case (6), whereas the combination of the digital microscope would detect the highest maximum number of evidence types in any one case (8). All other combinations would be able to detect a maximum of 7 evidence types per case.

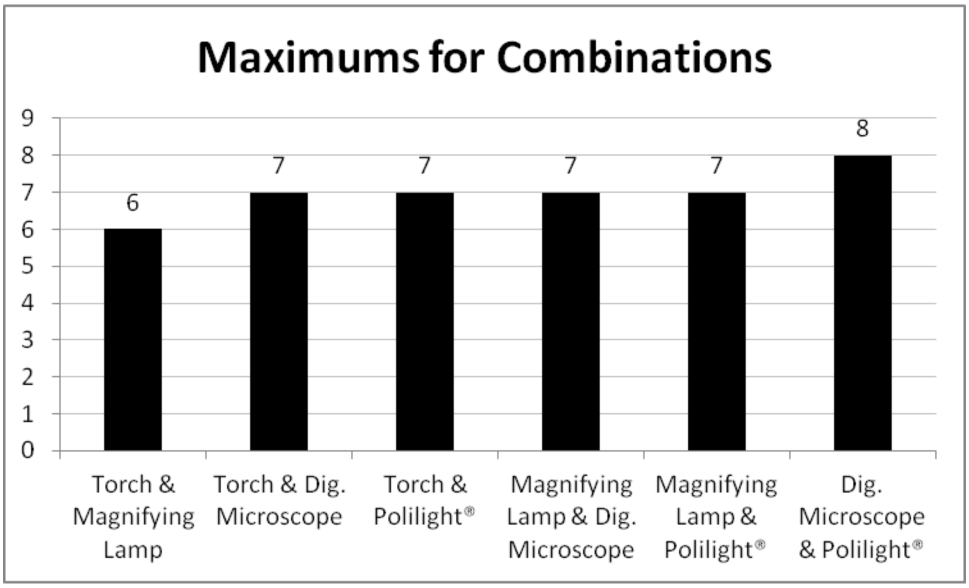

Figure 36. Maximum evidence types detected in any case for each equipment combination.

The magnifying lamp combined with the digital microscope would detect the least number of evidence types per case on average (mean = 1.73). The torch used in combination with the Polilight® would detect the most number of evidence types per case on average (mean = 2.58).

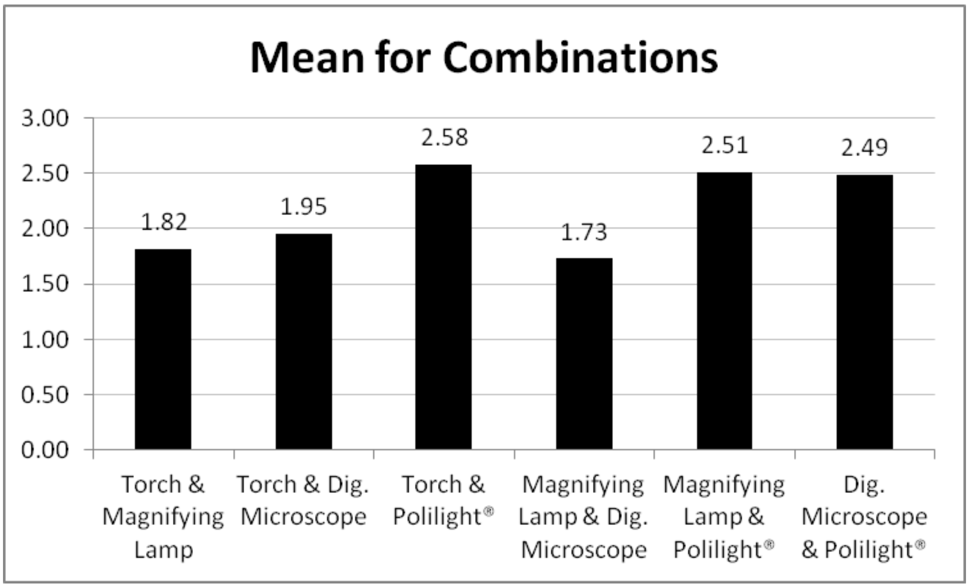

Figure 37. Mean number of evidence types detectable per case when equipment is paired.

Chapter 4: Questionnaire (See Appendix D)

A questionnaire was sent out to key role players in the forensic sciences. Seventeen replies were obtained. Five (29.4%) of these were from individuals working as pathologists and registrars, 1 (5.9%) was a medical officer, 6 (35.3%) were employed in a legal capacity (state advocates, public prosecutors, senior magistrates), 4 (23.5%) were individuals in the field of forensic science and analysis, and 1 (5.9%) was a medical doctor.

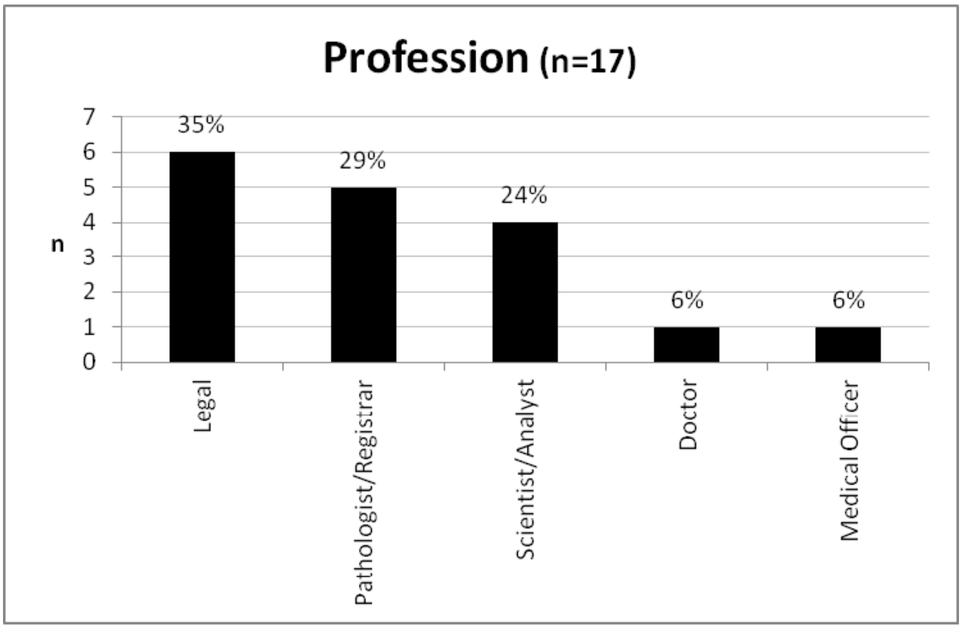

Figure 38. Professions of questionnaire respondents.

The respondents' experience ranged from less than a year to 30 years, with a mean of 14 years and 10 months (14.8 years).

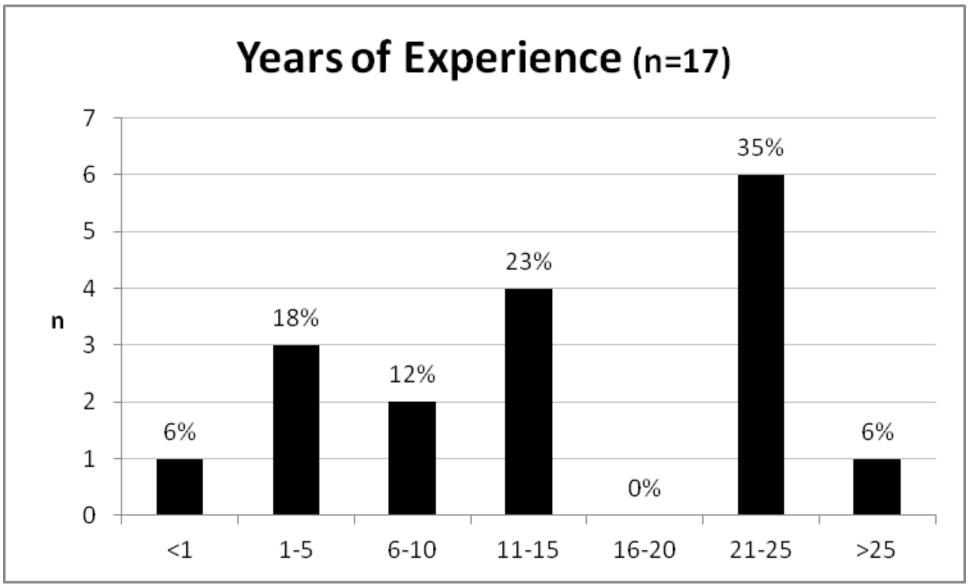

Figure 39. Years of experience of questionnaire respondents.

4.1 Question 1

Four (23.5%) individuals felt that trace evidence potentially connecting a perpetrator to a victim would facilitate and strengthen the judicial proceedings in all cases. Ten (58.8%) individuals felt that this would be the case in most instances, and 3 (17.6%) individuals felt this would be so in only some cases. No one felt that trace evidence connecting a perpetrator to a victim would be wholly useless to judicial proceedings.

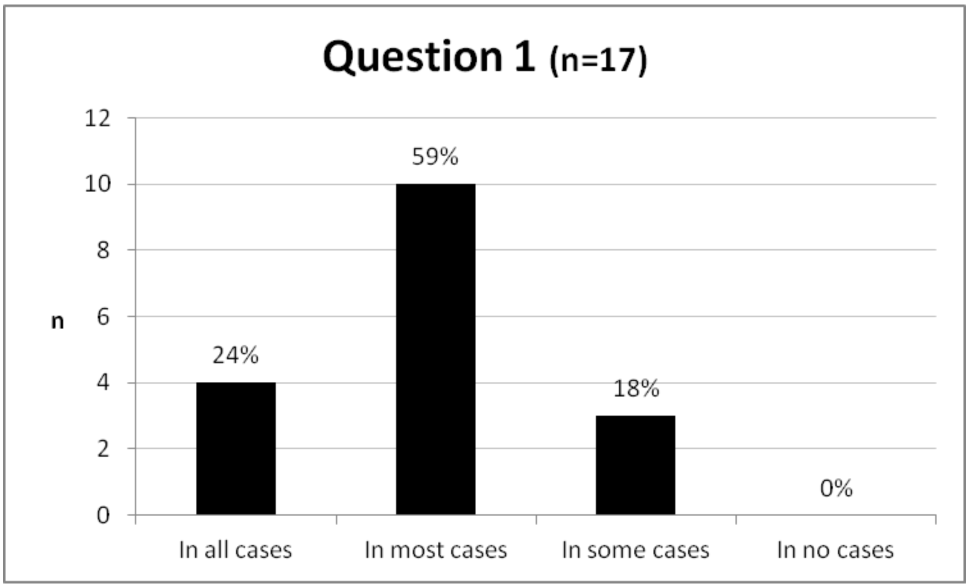

Figure 40. Responses to Question 1.

4.2 Question 2

The sentiment is not the same when considering biological evidence in the same scenario. Eight (47.1%) individuals felt that biological evidence would aid judicial proceedings in all instances and another 8 (47.1%) felt that this would be the case in most instances. Only 1 (5.9%) individual felt biological evidence would be useful only sometimes in the judicial proceedings. Again, no one felt that biological evidence would be without merit in a criminal case.

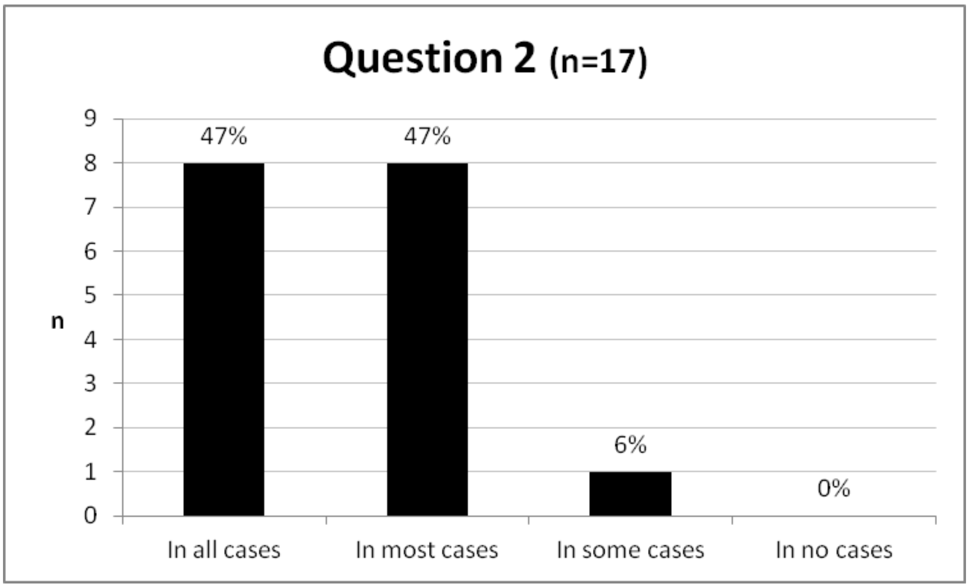

Figure 41. Responses to Question 2.

4.3 Question 3

Six (35.3%) people felt that fingerprints would be useful in all instances. Ten (58.8%) felt that fingerprints would be useful in most cases, and only 1 (5.9%) felt they only find use sometimes. Once again, their usefulness was not wholly discounted by anyone.

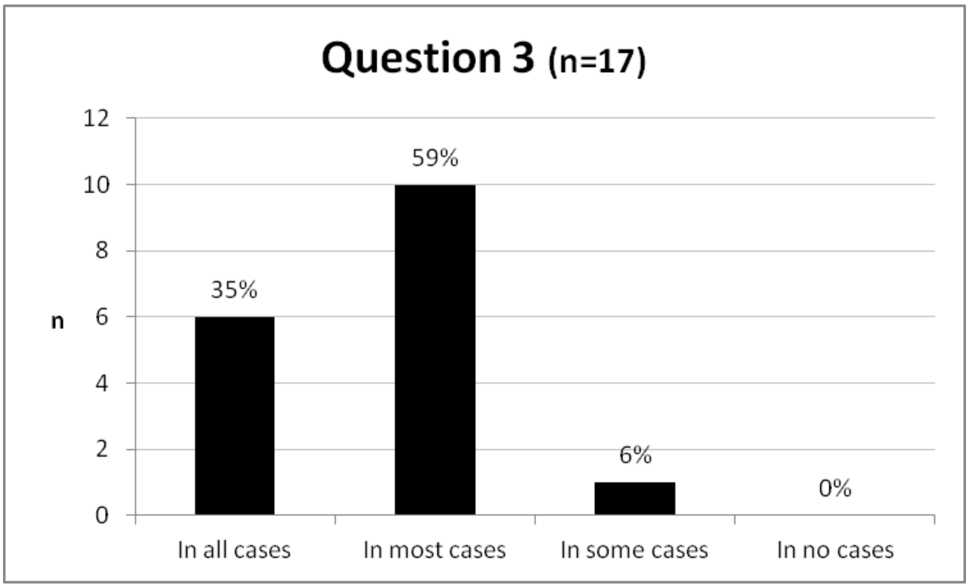

Figure 42. Responses to Question 3.

4.4 Question 4

Six (35.3%) individuals felt that technologies found to be useful for trace evidence detection in the mortuary would be useful in all instances in the clinical setting. Nine (52.9%) people felt this would be the case in most instances and 2 (11.8%) felt this would be the case only sometimes. None (0%) felt these tools would have no value whatsoever in the clinical setting.

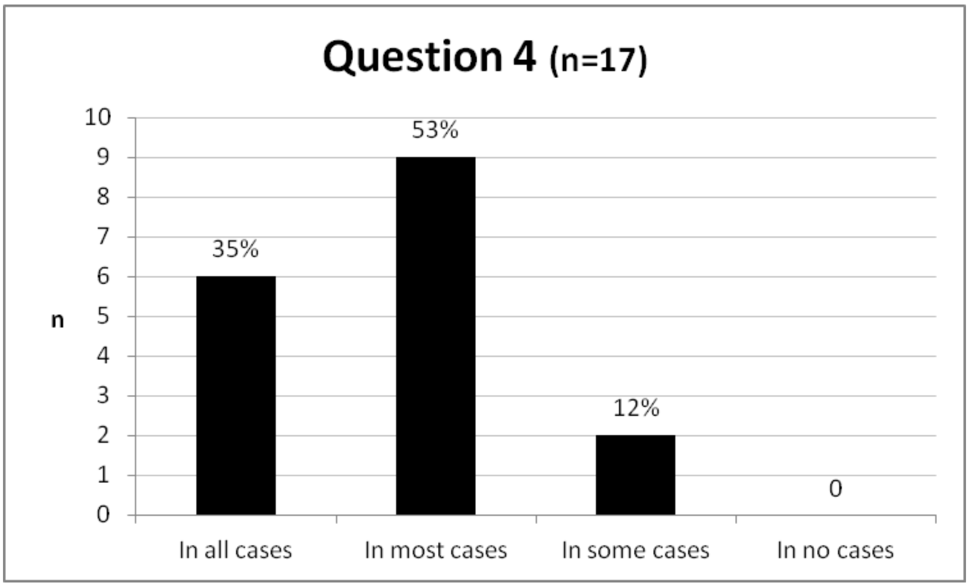

Figure 43. Responses to Question 4.

4.5 Question 5

Most respondents (64.7%) strongly agreed that tools found to be useful should be implemented as part of the routine in the forensic environment, with only 6 (35.3%) merely agreeing. No respondents disagreed with this proposal.

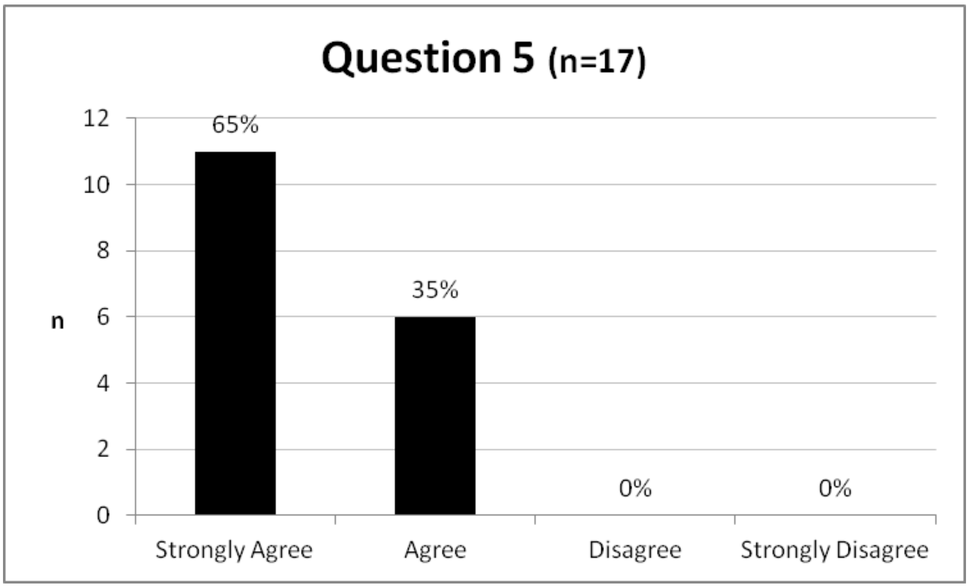

Figure 44. Responses to Question 5.

4.6 Question 6

Only 1 (5.9%) individual was satisfied with the current prosecution and conviction of criminals in our country, qualifying that the system in principle works, but the failures lie in the application and management of said system. The remaining 16 (94.1%) respondents felt the prosecution and conviction of criminals in South Africa needed to be improved.

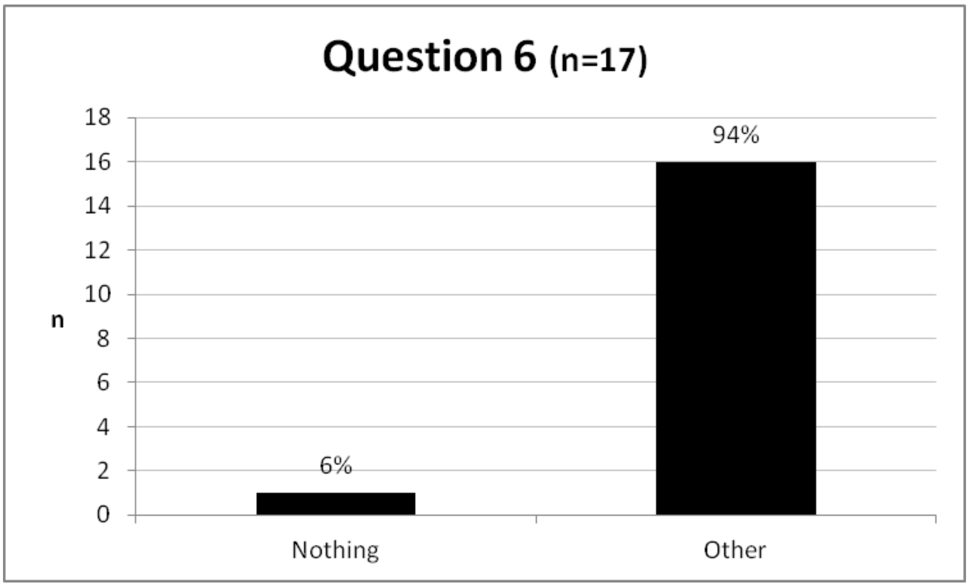

Figure 45. Responses to Question 6.

4.7 Question 7

Individuals often ticked multiple responses to the question of what factors compromise decisions to pursue cases as most individuals felt that the issue was multi-factorial. Eleven of a total of 38 responses (28.9%) indicated a lack of evidence as a main compromising factor. The same number selected police inefficiency as a problem area. Five (13.2%) respondents selected a lack of suspect as an issue, and 7 (18.4%) considered lab inefficiencies to be the cause. Other issues were selected 4 (10.5%) times as the root of the problem. Inefficiency of public prosecutors was mentioned in the comments as a contributing factor. Ignorance or a lack of training was mentioned as the reason for valuable evidence being overlooked.

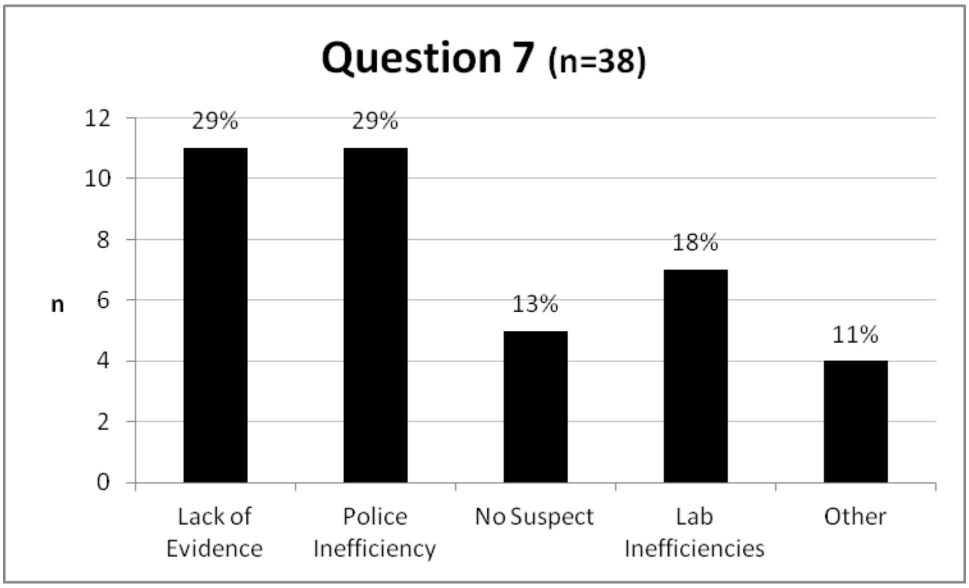

Figure 46. Responses to Question 7.

4.8 Question 8

In the evaluation regarding the main factors influencing whether a case leads to a conviction, the responses were once again multi-factorial. Ten out of 31 (32.3%) responses suggested that a lack of evidence is the main problem. Eleven (35.5%) responses mention police inefficiency as the main compromising factor. Lack of a suspect was only ticked once (3.2%), with lab inefficiencies and other factors being cited 4 (12.9%) and 5 (16.1%) times respectively.

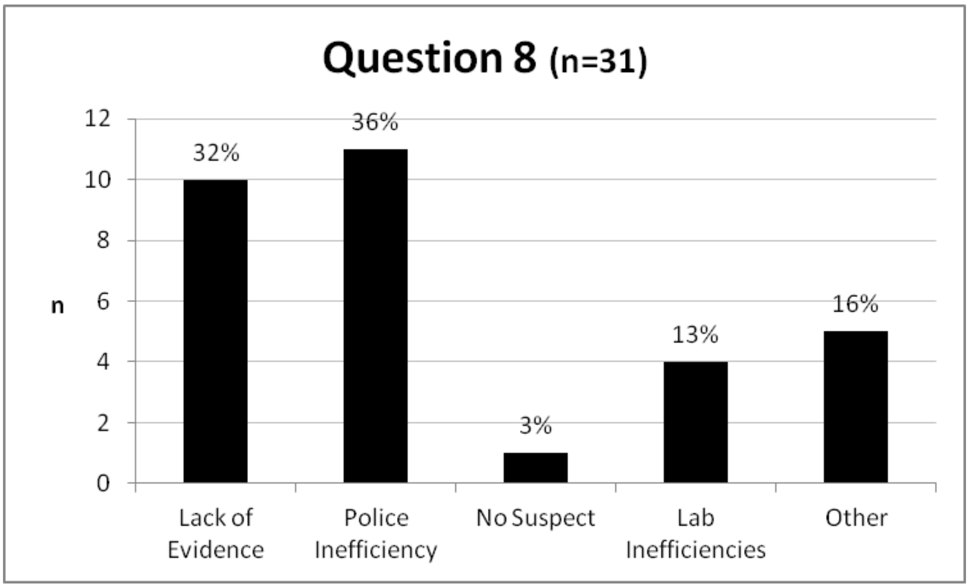

Figure 47. Responses to Question 8.

4.9 Question 9

When questioned how much additional capital investment into the improvement of trace evidence recovery was justified, the majority (52.9%) considered more than 50% to be justified. Four (23.5%) individuals considered 25% justified, 2 (11.8%) felt 10% was justified and 1 (5.9%) person felt that only 5% was justified. One (5.9%) individual felt they had no way of knowing how much would be justified. No one felt that evidence recovery was an area that did not require additional funding.

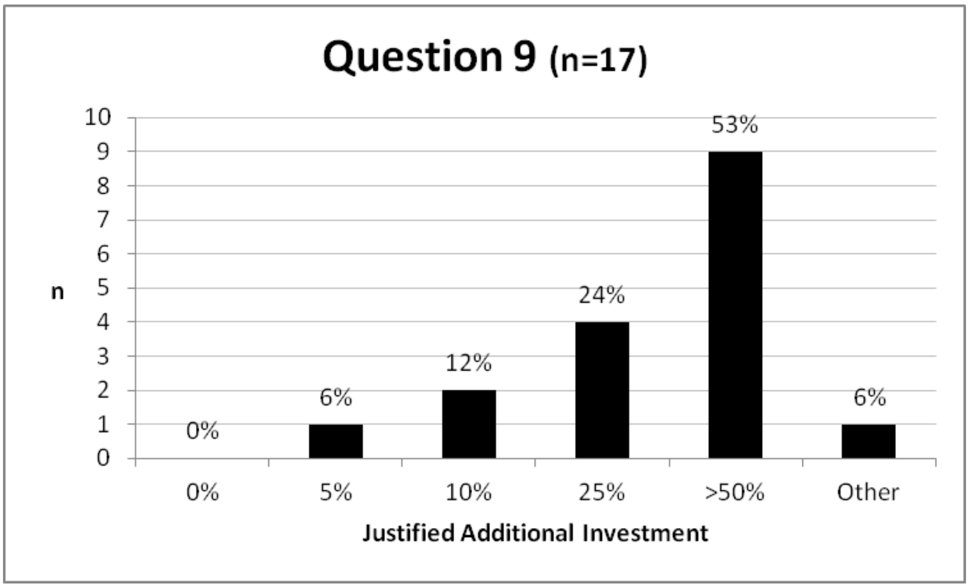

Figure 48. Responses to Question 9.

4.10 Question 10

Fourteen (82.3%) respondents felt that such technology should only be placed in the hands of specialist investigators, 2 (11.8%) felt that both police and specialists should have access to the technology, and only 1 (5.9%) respondent felt that existing police would be able to handle the responsibility adequately.

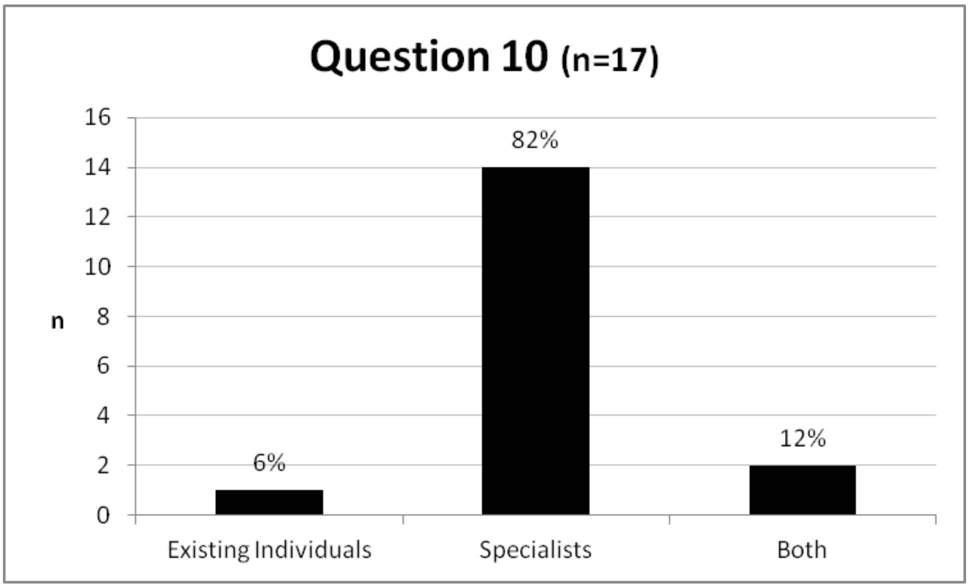

Figure 49. Responses to Question 10.

Chapter 5: Discussion

5.1 General

Other researchers agree that the latest equipment should be applied to forensic investigations.[88] Several factors need to be considered when comparing evidence detection imaging technologies. These include cost, ease of use, portability and evidence detection ability. These screening tools do not offer any form of confirmatory identification to the evidence discovered, but rather serve to greatly simplify the search by identifying key areas where collection or further analysis needs to take place.[97] This should minimize time expenditure and help focus otherwise daunting and overwhelming trace evidence recovery efforts.

5.2 Demographics

The majority of victims were male. This is in-keeping with the demographic for South African homicide victims,[19] and the Gauteng population as a whole.[16] According to most studies,[19,166-169] male individuals make up approximately 80% of homicide cases with rates more than three times those of female individuals.[10,170-171] Similarly, males make up 73% of PVA fatalities.[14,172] Other studies quote more even distributions between the sexes, but always with male victims dominating the statistics.[173-174]

Victims were mostly Black, which is also in-line with the typical South African homicide victim profile,[19] as well as the South African population demographic.[16]

5.2.1 Dark-skinned Individuals

The colour, absorbency and inherent fluorescence capabilities of the substrate on which a sample is deposited all influence the visibility and enhancement of the deposited sample.[110] The ability to detect biological stains using an ALS is highly sensitive to the surface on which the sample is deposited and ALSs struggle to illuminate evidence against dark backgrounds.[86,117] It was then hypothesized that evidence detection by the ALS would be diminished on darker-skinned victims. It was found that the Polilight® effectively reveals contusions on darker-skinned individuals which may not otherwise be readily apparent.

It was difficult to accurately gauge the difference in evidence detection as the number of Black victims greatly outnumbered the number of White victims in this study. Also, there was no means of standardization as to the initial potential evidence deposited on each individual. Keeping these problems in mind, it was found that there was no statistically significant difference between evidence detection ability on Black victims and White victims. This means that the results of international studies[109,133] conducted on fair-skinned individuals are applicable to South Africa's predominately Black population. This is one less hurdle to overcome in tailoring international systems to the South African environment.

5.3 External Cause/Circumstance of Death

Sharp force trauma was the most common cause of death for victims in the study, followed by blunt force trauma. This may have resulted in fewer traces being present for detection, as a weapon was more commonly between the victim and the assailant, whereas more physical-contact orientated causes of death – such as manual and ligature strangulation – would have potentially yielded more proof of contact between the victim and perpetrator.

5.4 Rape/Sexual Assault

Suspected rape or sexual assault cases have traditionally been managed with greater care at the PMLL in order to prevent the loss of potential evidence. This may have influenced this study's methodology to be somewhat biased towards suspected sexual offence cases. For the purposes of the PMLL, there is less interest in evidence that is easily dislodged and more interest in rape-related fluid stains that are less likely to be disturbed. It was also expected that evidence in truly trace amounts would have been missed anyway and that the most damning evidence (i.e. body fluids) would remain intact. Therefore, this was seen as justification for the removal of the clothing for analysis instead of hindering the pathologist further by examining the clothes *in situ*. The researcher was willing to risk the loss of a few loose items with the greater goal of finding fluids and other rape-related evidence.

Only female victims were suspected of being raped or sexually assaulted in this study. This bias was found to be highly significant. Race was not significantly associated with rape/sexual assault being suspected, but cause of death was highly significantly associated. Rape was not a suspected element of the crime in the majority of cases, meaning that the Polilight®'s renowned ability for body fluid detection may have been hampered by a lack of cases.

5.5 Skin versus Fabric

According to Schulz *et al.* (2007)[80] (Germany), there are no studies focusing specifically on the fluorescent properties of skin. Most studies using ALS systems focus on inert substrates which limits its applicability to the examination of human skin.[109]

Semen was not found to fluoresce on skin under illumination of a low intensity LED, but detection of the same stains was successful with the Poliray™, high intensity LEDs and the Luxeon™LED.[109] Semen stain detection on human arm skin was also successful with the Mineralight®, Evident Products CE, Bluemaxx™ BM500 and Bluemaxx™ Mini.[132]

Wood's Lamp has been reported to illuminate semen on human skin,[128-129] but Santucci *et al.* (1999)[130] found that semen samples did not fluoresce under Wood's Lamp on human skin. Wawryk and Odell (2005)[109] hypothesized that the reduced fluorescence of samples on skin may be due to something excreted in sweat or sebum on the skin, or that something in fibres causes biological samples to fluoresce better. Conflicting reports such as these make it difficult for one to decide which equipment would suit one's needs, and it is recommended that internal testing be conducted to find or tailor an instrument to fit an institution's specific requirements.

Wawryk and Odell (2005)[109] found that the fluorescence produced by samples on skin was too weak for adequate photographic documentation. What is seen with the goggles versus the photograph taken with the filter provided is often very different. The contrast is not as strong and the image appears dull as the flash cannot be used in conjunction with the Polilight® illumination. This may mean that the courts would have to rely on potentially unreliable observer reports and memory rather than more robust photographic records. Great difficulty was experienced in acquiring adequate photographs and training in this regard would be essential for real-world applications.

This struggle to obtain adequate photographs was not limited to the Polilight®. The digital microscope requires a very steady hand when pressing the capture button, and photographing through the magnifying lamp's lens also produces less than satisfactory images (See Figure 50).

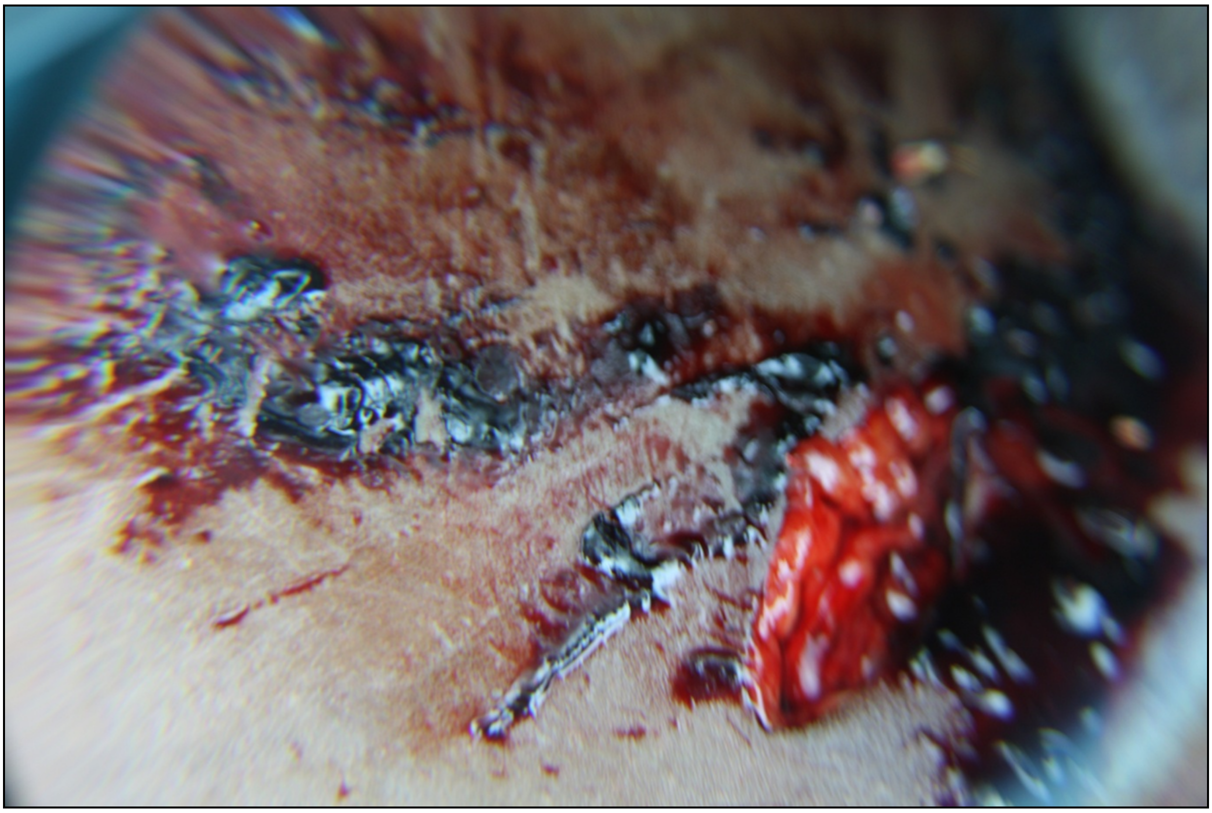

Figure 50. View through the magnifying lamp lens. Obtaining photographs through the lens was very difficult and mostly unsuccessful at portraying what the researcher could see.

Skin was examined by Lincoln *et al.* (2006)[112] before deposition of semen samples and areas already prone to fluorescence (false positives) were found. These included areas of dry skin or calluses and areas believed to have hand-cream present.[112] According to Wawryk and Odell (2005),[109] an ALS is well-suited for semen detection on clothing but less effective on human skin. Information gleaned from these types of studies is invaluable in understanding the application of ALSs to victims and suspects of crime.

5.6 Dry versus Wet Samples

In other studies, the substances were allowed to dry before examination.[109,111,116] Stoilovic *et al.* (1991)[116] found that untreated dry semen fluoresces very strongly. The field cases studied in the current study were examined after refrigeration, meaning that many of the biological samples deposited on the bodies were still in liquid state or were made so by the condensation created by the refrigerator. This may explain why readily visible wet samples were better seen by means of reflection than fluorescence in this study. Despite drying their samples, Wawryk and Odell (2005)[109] also found that reflection rather than fluorescence made samples easier to detect.

Biological fluids deposited on a living victim are usually dry by the time the victim presents for examination.[33] This makes other studies relevant for the clinical setting, but less so for the mortuary and crime scene environment where stains may still be wet.

A perplexing finding is that fluid stains assumed to be semen glowed as expected under illumination with the Polilight®, but known sources of passive seminal discharge (*i.e.* droplets on penises) did not glow well and were better noticed with the use of the torch (See Figure 51). This makes one question whether findings assumed to be semen are in fact semen or if there is another reason why these droplets do not fluoresce well. For example, the fluid may have different constituents between living and dead discharges or refrigeration and subsequent condensation may have diluted the samples. Wawryk and Odell (2005)[109] did not find a difference in fluorescence between azospermic and normal semen. Samples of the same fluid from different donors, as well as different samples from the same donor, all differ, and this heterogeneity may have unprecedented effects on the ability of detection methods to work effectively. It may just be that dry and wet samples do indeed fluoresce differently.

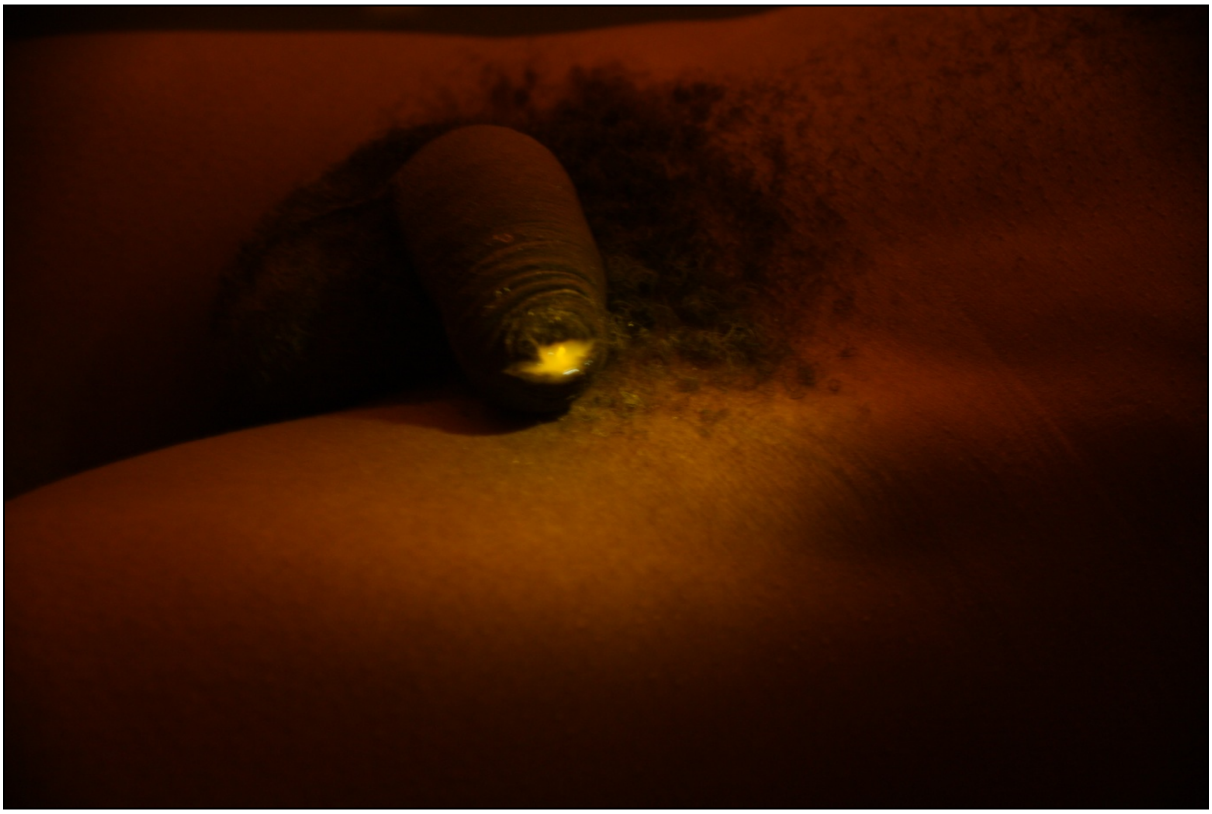

Figure 51. Suspected semen as seen with the Polilight®.

5.7 Delay in Examination

Wawryk and Odell (2005)[109] found that fluorescence detected on the initial day of examination was imperceptible on the second day. This highlights the need for immediate examination where a delay of even one day can impede investigations. This suggests that immediate examination at the scene would be preferable to waiting until the autopsy the following day. Alternatively, the bodies could be examined directly upon arrival at the mortuary, before refrigeration or the following day's autopsy.

5.8 Loss of Evidence

Bodies are not always fully clothed upon admission to the mortuary. This lack of clothing may be due to incomplete collection by the individuals who recover the body or the lower socio-economic status of many of the victims. Missing items (such as underwear) may alert one to foul play when there is in fact none involved. There were discrepancies in what the victim was noted to be wearing at the time of examination versus at autopsy in almost every clothing category, but only socks were noted differently with any statistical significance. Although slight, these discrepancies either point to a lack of detailed note-taking on one or the other party's parts, or a possible misplacement of clothing items between even the small distance of the autopsy and examination rooms. This could highlight a greater concern as to what could have potentially been lost over the far greater distance between the scene of the crime and the mortuary. This suggests a possible breakdown in the chain of custody. If items as large as shoes can go missing or not make it to the autopsy with the body, then trace evidence can just as easily be lost in this process.

5.9 Evidence Detection

Botanical samples were detected on more than half (58.2%) of the victims. The digital microscope found botanical samples most often, whereas the Polilight® performed the weakest in this area. As a common evidence type on the bodies of victims, botanical samples may be highlighted as needing more attention in subsequent analyses. The evidential value of such samples needs to be considered in context, however. These samples would have value if it was suspected that the body had been moved from its original location. If samples could be matched to a suspect's vehicle or clothing, these too could have high evidential value to place the suspect at the scene. Any evidence can prove useful, even if its true potential is not realised at the time of detection.

Similar evidential value applies to geological samples. 'Geological samples' was an umbrella term used to refer to dust, gravel, mud and sand, amongst others. These samples were present on the majority of cases (61.8%). Once again, the digital microscope detected these samples most often (60%), with the Polilight® detecting geological samples in only 4 cases (7.3%).

The magnifying lamp was able to detect all of the cases where glass was present. This earmarks the magnifying lamp as useful for PVAs and house break-ins.

Figure 52 & Figure 53. Glass fragments seen with the digital microscope. Depending on the size and angle of the fragment, it can often be harder to see with the digital microscope than with the naked eye, torch, or magnifying lamp.

Fibres and hairs were also some of the most common evidence types. The Polilight® was the forerunner in detection of this evidence type.

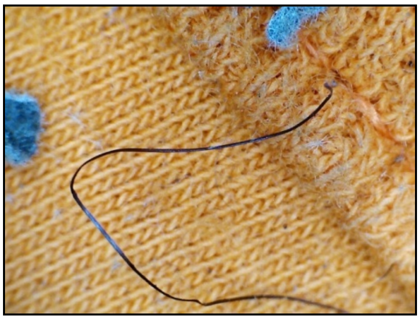

Figure 54 & Figure 55. Fibres/hairs seen with the digital microscope.

Wet and dry paint smears, as well as chips of paint, were detected in 23.5% of cases. Red paint chips were found on many of the bodies (See Figure 56), but this was later discovered to most likely originate from the body bags in which the bodies are contained. This kind of contamination can lead the investigative teams on a wild goose chase, perhaps causing them to search for a painted weapon (e.g. crowbar) or to suspect a hit-and-run rather than an assault. This could easily be avoided with the use of different body bags.

Figure 56. An example of the red paint chips encountered in many of the cases. It was discovered that this paint likely comes from the body bags used to transport the bodies. This type of artefact may waste valuable time and resources if mistaken for contributory evidence.

Fingerprints were only found on one body and from the context, appeared to be impressions made by the weight of the victim's own hand. The fingerprints were discernible with the torch and magnifying lamp but imperceptible with the digital microscope and Polilight®. The Polilight® instruction manual suggests that so-called "raw" fingerprints can be detected at 350nm and 450nm, but this was found not to be the case here.[113] This may be due to a lack of fingerprints present or an inability on the part of the equipment.

Other imprints were those which appeared to be caused by pressure from clothing and other constrictive forces (See Figure 57). They were found on 4 bodies (7.3%). The torch found the majority of these imprints (5.5%). The imprints were imperceptible with the digital microscope. These areas of constriction or pressure may highlight areas worth investigating for touch DNA, for example in cases where a victim was throttled.

Figure 57. Other imprint believed to be caused by clothing.

All of the technologies performed comparably in tattoo detection. Although not trace evidence in the true sense, being able to legibly decipher an otherwise obscure tattoo is useful in identifying an unknown victim.

5.9.1 Value of Evidence Detection Tools

The differences between what evidence was noted or seen by the pathologists and what evidence was detected using the evidence detection tools serves to demonstrate the value of said tools. They suggest either superior detection ability when using the tools, or inadequate note-taking on the part of the pathologists. Although the second option may be an element, it is also likely that the pathologists may not have noted certain evidence types if they were of the opinion that they were not of high evidential value to the particular case.

There was a statistically significant difference in the detection of many of the evidence types between the pathologists and the tools. This applies to botanical samples, geological samples, glass and other evidence. There was a statistically significant difference between the pathologists' note-taking of these evidence types and all the individual tools' detection abilities of the same evidence types. This indicates that any of the tools studied here would increase the likelihood of the detection of the above-mentioned evidence types.

Evidence categories which did not show a significant difference between the pathologists' detection and that of the tools were other imprints and entomological samples. Evidence categories that were not even mentioned in any of the pathologists' reports were plastic, paint, paper, fibres/hair, fluids, faeces, fingerprints and "red streaks". Once again, some of these omissions may be due to a difference in opinion on evidential value. They may also indicate the usefulness of the tools as some of the evidence types may not have been easily seen with the naked eye.

5.9.2 Usefulness of Evidence Found

It was hoped that comments could be made as to the usefulness of evidence found in the subsequent case outcomes. Significant delays experienced in South African laboratories and the legal system made this an impractical consideration, and this idea was done away with. The questionnaire conducted aimed to at least partially fill this void by obtaining key role players' perceptions as to the likely usefulness of certain evidence types.

There are unlimited possibilities as to what can turn out to be used as evidence in a criminal case. The innumerable evidence types combined with Locard's Principle suggest that evidence is ready and waiting to be found and potentially aid an investigation. It is true that the absence of evidence is not proof that an event did not occur, but the discovery of even the smallest physical trace can only add weight to an otherwise struggling investigation. With the improved sensitivity of DNA techniques, the discovery of even the smallest traces of biological samples at a crime scene or on a victim's body is extremely important.[96]

Trace evidence cannot be regarded as a prerequisite for convictions, however. Some studies on the prosecution and conviction rates in rape cases have found that the presence of semen bears less weight in the final success of a case than the presence of injuries on the victim's body.[45,175] Rambow *et al.* (1992)[45] reviewed cases from 1983. It was found that the presence of sperm was associated with successful prosecutions, but not on a statistically significant level.[45] The conviction rate of the 53 cases having a willing-to-participate victim and an identified assailant was 34%.[45] Discovery of a semen sample may not be extremely useful in a case where sexual relations are not denied, and the matter of consent is more important in matters of alleged rape.

A study by Ingemann-Hansen *et al.* (2008)[175] found no correspondence between successful conviction and sperm or DNA match in cases of sexual assault. This raises the question as to how useful the discovery of trace evidence will be in the administration of justice. In one case a suspect's and victim's matching testimonies meant that the glaringly contradictory laboratory results were ignored and considered irrelevant and the suspect was convicted and sentenced.[176]

Brown and Keppel (2011)[177] found that forensic evidence linking the perpetrator to the crime increases case solvability but does not have as much bearing as other factors. Universal rules cannot be applied when determining the significance of evidence found.

For example, the Polilight® may uncover innumerable fibres on a victim's body, but this has little evidential value if they originate from the blanket in which the body was wrapped and transported to the mortuary. It was noted which bodies presented at autopsy wrapped in a blanket as the researcher wanted to see if this correlated to a likelihood of finding fibres on the body of the victim. It was found that there was no statistically significant correlation between these two variables.

When some of these bodies are viewed with the Polilight®, the entire body surface glows with fibres. It is virtually impossible to collect all this evidence in the hopes of finding one or two key fibres which would indicate the perpetrator's clothing, lodgings or car etc. Similarly under the Polilight®, a multitude of flecks would fluoresce. It soon became apparent that it would be impractical to note every single one of these nondescript flecks as they could not be quantified, identified or their significance gauged.

Many of the victims are unkempt or of a lower socio-economic class meaning that clothing is often soiled with fluids, dirt, detergent marks, old paint smears etc. This can also be confusing to the investigation. Similarly, condensation from the fridge can be mistaken for foreign fluid and time can be wasted investigating it. The researcher used their discretion as to whether a trace was noteworthy.

As would be expected, the combined force of all the techniques together resulted in the most evidence types detected per body. Standing alone, however; the digital microscope detected the most evidence types per body and the Polilight® detected the least. The consideration here, however; is the usefulness of the evidence types that each is able to detect. More evidence types may be detectable by one method over another, but the seemingly weaker performer may detect more significant/valuable evidence types than the technique which is able to detect all varieties of less useful evidence.

It is difficult to measure the usefulness of one evidence type against another, as an expert in the one field will place more weight on his evidence type than an expert in another field would. Also, there are cases where an unexpected and uncommon evidence type leads to the biggest break in a case and must therefore be seen to be significant. To the general public, thanks to the CSI Effect,[178] DNA evidence is probably seen to bear the most value in criminal cases. This is corroborated by the extensive literature regarding the Polilight® whose strength lies in biological specimen detection.

It may seem that the odds are not in the investigator's favour, but the presence of even slight traces is confirmatory of a recent encounter between the victim and suspect, which means that although samples are not found as often as hoped for, the few that are found have the potential to contribute to the subsequent investigations.

5.10 Clinical Application

It was hoped that the tools investigated in this study would find application in the clinical forensic setting. Some equipment may be considered intrusive and uncomfortable for a victim[89] in the clinical setting; an issue which is less problematic in the case of deceased individuals. The torch, digital microscope and magnifying lamp have no known health risks for the user or a living subject. The direct contact and slow and steady investigation required by the digital microscope are contra-indicative for clinical use. The torch and the magnifying lamp offer the least invasive examinations for the living patient, and the magnifying lamp already finds application in the dermatological setting.

In terms of clinical application of these systems, the ALS poses the biggest obstacles despite being recommended for clinical forensic use by other authors.[112,128-129] Wawryk and Odell (2005)[109] have cast doubt on the applicability of an ALS in clinical practice. They found that the ALS was not particularly effective in semen detection on human skin.[109] They hypothesized that a more intense light source would probably be more effective in revealing semen and other samples on skin, but this is likely to increase the potential health risks and damage the skin.[109]

Protective eyewear would be needed for both the patient and the clinician. The goggles need to be changed depending on the wavelength used and additional goggles need to be purchased if other individuals are to be present during an examination session. The UV wavelength is potentially harmful to the user and all the wavelengths are very bright and potentially harmful to the eyes, and even with goggles, barely stand to be looked at for more than a few minutes at a time.

The Polilight® was set down on an item of clothing that was being examined and in the time it took for the researcher to write down one sentence, a hole was burnt into the fabric by the intense heat. This has implications for the Polilight®'s applicability in the clinical setting on live patients as patients can obviously not be subjected to harmful procedures unnecessarily.

Individuals are already concerned over the potential harm that a brief X-Ray can cause and it is unlikely that living subjects would be willing to bear the discomfort and possible harm caused by a laborious high-intensity full-body search with an ALS. Lincoln *et al.* (2006)[112] suggest the inclusion of the ALS into the sexual assault victim evaluation as opposed to being a replacement for the current protocol.

The equipment studied here is not intrusive and should only cause a living victim slight discomfort at most. It must be kept in mind that these short-term discomforts need to be weighed against the long-term benefits of obtaining justice for the victim.[89]

5.11 Methodological Constraints and Recommendations

The recovery of trace evidence in this study depended on several factors. The researcher had no control over how the body was handled or transported, beyond asking the mortuary staff to be careful. Useful evidence may have become dislodged and been misplaced or lost during these processes. The researcher was not present at any of the scenes where the bodies were collected and is therefore unable to comment on the care taken by individuals there. There was the unavoidable risk of contamination from any member of staff or other crime scene and/or morgue attendees who came in contact with or close proximity to the body. For comparative purposes, a study testing these tools and other equipment at the scene would prove valuable.

As the study was conducted under field conditions, there was no way of knowing the initial potential amount of evidence to be found on each body; compromising any attempts at quantitative analysis. Evidence was given a likely identity based on appearance, but this could not have been conclusively known without collection and further laboratory analysis.

This study was conducted in a dynamic setting, where it was not always possible to handle each case exactly the same; which is desirable for more structured studies. Examples include cases of suspected sexual assault where more time was spent examining the thigh area and the ties/gags used on bound victims. Clothing was removed prior to examination to cut down the inconvenience and time expenditure for mortuary staff and the pathologists, which also meant that evidence may have been lost or dislodged. Some subjects had their extremities bound and these ties needed to be cut before clothing could be removed for examination.

Although mortuary assistants were asked to handle the bodies and clothing as carefully as possible, there is no guarantee that some shifting and loss did not occur. There was an initial intent to note the bodily locations where evidence was found to perhaps delineate any "hotspot" areas of deposition. Due to the above-mentioned factors, this aspect of the study was done away with. It is proposed that subsequent studies could be conducted in the future to identify trace evidence deposition hotspots.

The nature of the deaths of the majority of subjects studied here necessarily meant that both the bodies and clothing of many of the victims were covered in blood. Blood, vaginal deposits and faeces can mask the fluorescence of semen on fabric.[110] For this reason, blood-soaked clothing was not examined. It is difficult to handle and it was expected that the excessive blood flow would have dislodged or obscured any trace particles or other stains. Similarly, bodies often come to the PMLL covered in mud, dirt or grass as they are left for dead in open veld or alongside the road. It should be realised that other possible evidence may have been obscured by more superficially deposited substances and this factor may have further reduced the amount of evidence detected in this study. This is yet another issue encountered in the field setting and may not be otherwise considered in more controlled studies.

The examinations were allowed to be conducted unheeded, on the condition that no actions compromised the integrity of the investigation or obstructed the ends of justice. In keeping with this, the tools tested were chosen for their non-destructive nature, where the examinations would not compromise any subsequent evidence collection or the autopsy itself. In the case of suspected rape/sexual assault, vigilance on the part of the pathologist meant that they insisted on performing the sexual assault evidence collection kits before the researcher was allowed to examine the body and possibly notify them as to additional locations to swab or comb etc. This meant that some evidence may have been dislodged or removed/recovered before the researcher had a chance to locate it. Additionally, some clothes and evidence (such as gags and ties) were collected for evidence by the pathologists or attending investigating officer before there was a chance to examine them.

Cases were selected over a longer period than initially visualized, as sometimes a pathologist or prosector would accidentally wash the body before it was able to be examined, or examination would begin and it would then later become apparent that the individual was collected from the hospital and not the scene. Further administrative issues such as initial case identification and preliminary cause of death also meant delays in data collection.

Differences in what the pathologist noted in their reports and what was found by the evidence detection tools may not be a true reflection of the tools' abilities as the pathologist may very well have seen the traces but only mentioned what they felt was noteworthy in their reports.

Another potential study would involve a set of contrived material to see how effective the equipment is in detecting known amounts and types of trace evidence in order to offer a comparison to the field condition findings. This would attempt to gauge the tools' abilities to locate evidence that is known to be there; giving more confidence when conducting searches on real cases as to the chances of locating evidence.

Each evidence type is best illuminated by its own set of wavelengths and there is no single all-encompassing wavelength which can reveal all evidence types.[86] Taken as a whole, the best general wavelength and goggle combination for detecting biological stains is 450nm with orange goggles.[119] In the current study, only one wavelength – albeit the purportedly best general wavelength[119] – was tested. This necessarily limits the deductions that can be made from the data as it is not truly representative of the ALS unit's full capabilities and some evidence may have been missed. Many studies have already been done to devise the best wavelengths for each type of evidence and conducting the current study with all the wavelengths available would have been far too time-consuming.

Although 450nm was used as the standard examination wavelength for all cases, the researcher also dabbled with the other wavelength options offered by the Polilight®. Trace evidence detection literature often focuses on UV light.[116,134-135,137-139] UV was found to be weaker than expected and provided poor contrast in the few elements it could detect. The 450nm wavelength illuminated marks not seen under UV illumination.

The Polilight®, especially the IR option, proved particularly proficient in highlighting faint or invisible tattoos. This function could prove useful in victim identification. Four-hundred and fifty nm, UV and 555nm were found not to add much contrast to these tattoos. Additionally, a small bruise was seen only under IR and not any of the other wavelengths. After use of all the wavelengths on several cases, it was confirmed that 450nm is the strongest, brightest and offers the best contrast for the things it does manage to detect.

5.12 Personal Remarks

5.12.1 General Examination

Each examination proved slow and tedious and at times seemed to work on the patience of all members of staff at the mortuary. This type of pressure may push one to want to rush and gloss over areas assumed to be unimportant. The introduction of this type of intensive external examination to the normal autopsy routine may be met with some resistance initially. Having a stream of cases that do not produce many results can also lead one to be lackadaisical and may introduce a loss of meticulous care as the examiner may begin examinations with the mindset that they are unlikely to find anything of value.

Despite efforts to reduce bias by using the instruments in the preconceived order of weakest to strongest, a tendency still came about to focus on areas where evidence had already been located with the previous tool, although of course, full body scans were still conducted. The core methodology of the study made it impossible to conduct a fresh blind search on the entirety of the body with each instrument without introducing other examiners and the issue of inter-observer variation.

5.12.2 Torch

For a small and simple light source, the torch is fairly pricey, but not to a point that outweighs its usefulness. It is compact and lightweight and the lanyard ensures it is not dropped. In addition, the belt clip allows it to be easily carried around in a hands-free manner while still being easily accessible. The illumination it provides is very bright and highlights reflective materials not noticed by other methods.

The torch provides a bright white light which was found to sometimes blanch evidence such as mud and dirt; making it harder to see (See Figure 58). Most of the evidence detected with the use of the torch was already visible to the naked eye. The researcher is of the opinion that the normal torch light added more value in a darkened room (when the overhead lights were not on) as the bright fluorescent lights of the mortuary weakened the impact of the torch light. This suggests that a well-lit examination environment can mostly replace the need for a torch.

Figure 58. The torch creates a bleaching effect when used at 90 degrees to the surface, but this is far less severe than the effect caused by the white light setting on the Polilight® (Also see Figure 64).

5.12.3 Magnifying Lamp

Although well-priced, the magnifying lamp proved slightly impractical for a general body search. It is cumbersome to set up and use. Its requirement of needing to be firmly attached to a stationary and suitable surface added to its difficult-to-manoeuvre nature. The fixed point of reference is limiting and means that the body has to be manoeuvred a lot in order to conduct a full examination. It is not portable and therefore does not lend itself to use at a crime scene. The clamp does not suit all counter tops, and a block of wood had to be used in this study to adjust the available surface. The arm does not stretch very far which means removing and reclamping the lamp often or attempting to manoeuvre the body – a difficult task when conducting the search solo. Although this is possible in a mortuary setting such as the PMLL where the bodies are on mobile gurneys, it would still be much easier and more efficient to have a portable handheld device so that the researcher can rather walk around the body during the examination. If the unit were portable, its usefulness would be considerably greater.

The angling and small field of view mean that only one person can look at a time, making consultation with colleagues difficult. The large region of blur surrounding the small field of focussed view is distracting and confusing to the viewer and removes the exhibit from its context somewhat. Also, one needs the lens to be close to the object being inspected as well as one's face, making access to the image even more difficult as well as increasing risk of bumping the subject and dislodging evidence or contaminating the subject as well as putting the examiner's health at risk.

The magnifying lamp proved useful in the visualisation of suspected drag marks and helped in the determination of directionality by means of the skin tags. When it came to faint non-professional tattoos, the magnifying lamp did not aid in bringing clarity to the design or wording.

5.12.4 Digital Microscope

The digital microscope proved relatively simple and easy to set up and use. Extensive training in its operation is not required, and a lay person would be able to operate its basic features without much trouble. It is lightweight and compact with a convenient stand and controllable brightness dial. Once correctly focused, the microscope offers amazing detail and allows one to take images and videos instantly. Considering its capabilities, it is extremely cost effective and was locally sourced.

It is very easy to manoeuvre around the entire body, provided an additional USB extension lead (not included) is connected for better reach. The ability to view the images in real time on a laptop screen are both a bonus and a drawback, as the examiner has a large view without needing to put the microscope up to the eye, but it also means that the microscope is constantly anchored by this stationary point and makes scene use slightly less feasible as a laptop must follow it everywhere.

One drawback is that the device needs to be pressed directly against the surface of interest in order to obtain a clear focussed image. This means that the device gets dirty and also disrupts evidence and contaminates the body. It is easy to lose one's place as the slightest hand movement disrupts the view and the high magnification means it is difficult to orientate oneself. It is not suitable for a full body examination as it is extremely tedious to comb over every inch of such a large surface area. It is ideal for examining specific lesions and areas of interest, however.

The digital microscope serves little purpose in examining fluids. A distracting reflection is created by the internal lighting of the microscope (See Figure 59). It also does not aid in the examination of tattoos as the high magnification takes a small portion of the larger tattoo out of its context and makes it impossible to decipher the design as a whole (See Figure 60).

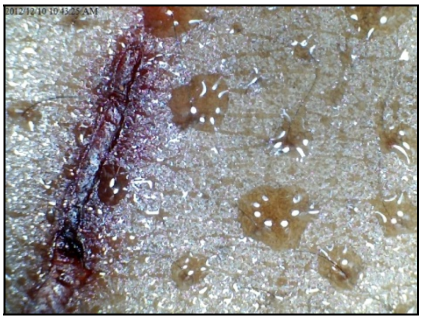

Figure 59. Reflection of the lights of the digital microscope creates confusing artefacts in reflective materials, especially fluids.

Figure 60. Tattoo seen with the digital microscope. This tool does not seem to add value to the inspection of tattoos as the increased magnification does not add any clarity.

The lower magnification (20X) on the digital microscope produces the best picture. The higher magnification (400X) is overwhelming to the untrained eye and as the skin is a soft surface and direct surface contact is required, it is very difficult to get a clear picture at the higher magnification. A very steady hand is required as even the movement to press the capture button often results in blurring of the image. Also, there is only the option of the two magnifications with no interim zooming that provides a focussed image. This often meant that an area of interest would be discovered at the lower magnification, but the focal point would be lost while carefully trying to hold the device in place and simultaneously turning the magnification dial. A smoother dial design or a separate button option for zooming/capturing (perhaps operated from the computer) may work better.

The digital microscope was useful for examining wounds. This served to confirm whether wounds were in fact lacerations or incised wounds (i.e. tissue bridging) and also served to show particles within the wound or on the edges (See Figure 61), as well as allow for an appreciation of the depth of the wounds (i.e. differentiate a stab and incised wound) (See Figure 62). The true usefulness of the digital microscope was demonstrated when evidence believed to be gravel was seen to in fact be insects (See Figure 63). The digital microscope is probably better suited to examining specific particles rather than locating them.

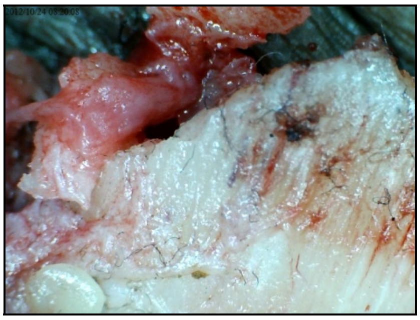

Figure 61. Traces particulates adhering to the break in a bone can be seen with the digital microscope, perhaps indicating an order of events or that clothing was present or absent at the time of injury or that the body was moved from a site with matter foreign to where it was recovered.

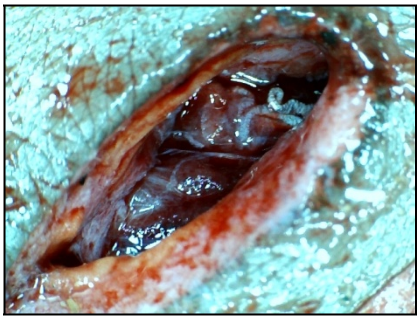

Figure 62. Some appreciation of the depth and nature of a wound can be gained from examination with the digital microscope.

Figure 63. An insect – previously believed to be gravel – seen with the digital microscope. This is an example of the capability of the digital microscope to add clarity and detail to otherwise obscure trace evidence.

5.12.5 Polilight®

The Polilight® highlights foreign debris which would not be seen with the other equipment under normal lighting. The Polilight® was useful in determining if a suspect mark was fluid or a birthmark as it highlighted and clarified the edges. It served to differentiate between two similar looking stains. To the naked eye they looked identical, but illuminated under the Polilight®, one shone red and the other did not fluoresce. The Polilight® was also found to offer better definition and contrast to already visible marks. Glass fragments were not well detected by the Polilight®. This somewhat limits its value for vehicle accident cases.

The Polilight® was able to show that one elderly victim's teeth were not all real, as some fluoresced whilst others did not. Exposed bone glows yellow under 450nm with a high contrast against skin. This feature may be applicable to mass disaster recovery efforts especially where severe mutilation and dismemberment have occurred (e.g. plane crashes). The researcher cannot comment whether burnt bones from charred remains would react in the same way as none of the cases in the study involved burnt bones.

The Polilight® is potentially oversensitive for non-contributory specimens to the point of being distracting from more significant findings. What was assumed to be mud often fluoresced brightly under Polilight® illumination. This is confusing and may lead one to think one has found something more significant than one really has. In contrast to this, the researcher also experienced much frustration in cases known to be the result of violent altercations where nothing more than fibres could be found despite the use of every wavelength available.

The Polilight® is comparatively very expensive and individual laboratories would need to weigh the benefits of the equipment versus the cost. It is unlikely to be a financially viable option for all institutions. Despite being advertised as a portable device, this description is misleading as the particular model is very heavy, large and cumbersome and would not be practical for use on the scene. It needs to be plugged into a mains power supply, which further limits its use at crime scenes. It requires a fair amount of assembly and time to figure out its usage and the instruction manual alone is not adequate to fully equip an examiner for evidence detection. It is the recommendation of the researcher that only specific trained personnel be allowed to care for and operate it.

The Polilight® takes a long time to turn on. This is especially inconvenient if one turns it on and off often. The supposedly flexible light guide (silver tube) on the Polilight® is less flexible than desired and springs out of position when set down, often knocking things off the counter or falling. This would work better if it were as flexible as the IR light guide (black tube). It was also found that the Polilight® performs optimally in a darkened room despite advertising claims that this is not necessary. This does not lend itself easily to scene usage.

5.12.6 Training

All the equipment tested is fairly easy to use, but can still be put to best use with some training. The instruction manuals are mostly self-explanatory, but practice and experience serve more use. The torch is the easiest tool to use untrained, followed by the magnifying lamp. The ALS and digital microscope require more practice and know-how to achieve adequate results.

The large case load and already heavy burdens placed on South African pathologists means that one cannot reasonably expect them to personally conduct further in-depth examination of the bodies with the time and attention that it requires. Keeping this in mind, this researcher proposes to rather empower people to serve as specialist criminalists to take on this responsibility and aid the pathologists in specific cases.

Strict training for select individuals in evidence detection and recovery will make the investment of funding more worthwhile as equipment will be cared for and put to the most effective and efficient uses. Rigorous training for all individuals involved with evidence needs to be enforced to limit the amount of loss and ensure the integrity of the chain of custody. The best equipment in the world in ignorant or careless hands is simply money wasted.

5.13 Comparisons, Combinations and Alternatives

5.13.1 Comparisons

Soot and ash from burns were seen with the use of the torch, but did not fluoresce under Polilight® illumination. A large bruise to the sternum of a victim was readily visible with use of the Polilight® but otherwise invisible under the torch's white light illumination. The Polilight® negates the reflective shine of fluids and objects, whereas the torch is best at picking up this property. They were not detected by the Polilight® if they were not fluorescent. The Polilight® used on a shiny fluid however, served to differentiate between a bodily fluid and condensation from the refrigerator as condensation does not fluoresce. Mould or fluid on the feet of one victim fluoresced brightly, whereas it was barely discernible with use of the torch.

When examining a dust-covered tattooed body, the magnifying light served to examine the overlying dust rather than the tattoo, whereas the Polilight® negated the dust and highlighted the tattoo. On an assault case, a fragment of glass was located on the victim's clothing by means of the magnifying lamp. In retrospect, this item was visible to the naked eye but went unnoticed until the body was examined under a higher magnification. This kind of evidence may serve to set an investigation on the path of finding the driver of a hit-and-run incident rather than the previously thought assault. However, consultation with the attending pathologist led to the conclusion that the assault hypothesis was stronger. The pathologist deemed it unlikely that an isolated fragment of glass would transfer to the victim during a PVA and was more likely to have been picked up from the ground where the body was lying. This example goes to show that expert knowledge and experience have to be applied regardless of the findings, and evidence has to be treated on a case-to-case basis in order to determine the usefulness of said evidence.

The torch is best suited to detecting impressions, tattoos, paint, and other easily visible evidence. It would most certainly find use in detecting some evidence and can easily accompany the pathologist/investigator to the scene, but it does not particularly serve in uncovering less obvious evidence. Impression evidence has its uses but alone does not justify investment for the PMLL.

The magnifying light would serve best in the investigation of PVAs as glass, paint and other evidence were best detected with this tool. PVAs make up a large portion of the case load admitted to the PMLL and investment in this relatively cost-effective tool may be justified.

The digital microscope was best at detecting particulate evidence, such as botanical, geological and entomological samples. This would recommend it for the investigation of suspicious deaths where clues such as foreign flora may indicate foul play. This would perhaps find most use in a laboratory or high profile death investigation setting.

The Polilight®'s strength lay in fluid and fibre/hair detection which recommends it for the investigation of rape-homicides. As mentioned before, rape-homicides are given considerable attention at the PMLL and investment in an ALS such as this is worth consideration.

	Torch	Mag. Light	Dig. Micro.	Polilight
Price	R499,00	R461,95	R1199,00	R395 000
Weight	Light	Medium	Light	Heavy
Ease of use	Easy	Medium	Medium	Medium
Portability	High	Low	Medium	Low
Time	Low	Medium	High	Low
Training Required	No	No	Some	Yes
Evidence Detection Ability	3rd	2nd	1st	4th

Table 3. Summary of Key Findings

5.13.2 Combinations

Although no one technique tested in this study stands out as the all-star performer, a combination of these systems – or similar ones – may be the answer. An attempt was made to use the illumination from the ALS with the digital microscope whilst turning off the built-in microscope lighting. The main issue encountered with this idea is that the photographs taken with the digital microscope do not have the required filters meaning that the evidence can only be viewed successfully in real time. A smaller version of the camera filters supplied would need to be made to fit onto the digital microscope to achieve the desired result. Also, the digital microscope has to have direct contact with the surface it is examining and the Polilight® can therefore only offer slight illumination as it has to be supplied from the side at an angle.

Schulz *et al.* (2007)[80] combined the magnifying properties of a dissecting microscope with the illumination capabilities of a tuneable light source (Mini Crimescope® MCS 400 by SPEX Forensics) in an attempt to locate epithelial particulates. This method appeared to be effective and required less time and effort than other approaches.[80] The light source inherent to the microscope was forfeited in favour of using only the illumination provided by the ALS.[80] The microscope needed to be fitted with a filter similar to the ones used on cameras for photographing fluorescent images.[80]

There is no point in combining the torch with any of the other tools as each has their own inherent light source. The bright white light option on the Polilight® makes the torch fairly superfluous although the brightness of the ALS is almost too intense and ends up bleaching the object under examination, making details invisible (See Figure 64). This is counterproductive, although it may be well suited to casting strong shadows.

Figure 64. The white light option on the Polilight® may be considered too strong for this kind of examination and adds little value when held at 90 degrees to the subject.

The magnifying lamp can be combined with the Polilight® with some success. The main drawback was that the cumbersome manoeuvring required by both tools was amplified by their combined use. A device has already been designed which combines these two tools. It is the Crime-lite® ML2. Much like the magnifying lamp used here, it has an anchored extendable arm but the magnified viewing lens has multi-wavelength high intensity LED-illumination.[179] This tool is suitable for examining clothing or objects on a countertop.

5.13.3 Chemical Counterparts

The ALS is purported to be less sensitive at biological fluid detection than its chemical counterparts.[86] This suggests that lower dilutions of biological fluids – and by extension, evidence in true trace amounts – can be missed by means of an ALS alone. It should be considered however, that without a tool such as the ALS to give an indication of where chemicals should be applied, one would end up treating an entire surface (or body, in this case) with a potentially expensive and harmful chemical. This is the approach applied currently in the Evidence Recovery section of the Biology unit in the SAPS, but small crime scene exhibits and items of clothing do not offer the same obstacles as a human body – living or dead.

Chemicals are often carcinogenic or cause permanent changes to the substance or substrate. The steady application of a chemical with the subsequent wait for the appropriate reaction would be far more laborious, time-consuming and almost unbearable for both examiner and living subject. Tools such as the ALS aim to indicate areas of interest so that a sample can be quickly collected and tested away from the subject. This should go towards minimizing the discomfort and inconvenience experienced by the victim.

Kobus *et al.* (2002)[110] found that semen stains that fluoresced weakly after washing did not respond to the acid phosphatase test. This means that the fluorescent components, in semen at least, if not other substances, are more resilient than the components reactive to typical chemical testing.[110] This pinpoints a fluorescent method as being more sensitive than some of the current chemical tests available, albeit less specific.

Although the ALS is estimated to be 50 000 times less sensitive than luminol in the detection of bloodstains,[120] its general applicability to most biological fluid stains recommends it for use in a preliminary body search initiative.[55] The other systems also have the advantage over chemical options of being able to detect several types of biological evidence,[55] whereas chemicals are typically tailored to each evidence type. The lack of requirement for a chemical to be used, as well as its ease of use, makes an ALS a popular crime scene scanning tool despite apparent drawbacks.[86] The same would apply to other tools, should their capabilities be deemed useful for a specific institution's needs.

5.13.4 Alternatives

An illuminated magnifying glass may be able to serve the same function as the magnifying lamp whilst being portable. As stated previously, the torch may be mostly replaceable by a well-lit environment.

Alternatives to the ALS (eg. LEDs and lasers) offer their own obstacles[106] and a consensus cannot be reached as to which system is ideal for the crime scene, mortuary and clinical settings. Lasers have the highest power but are typically more expensive, heavier and less versatile than other ALSs.[106,108] Low intensity LEDs were unable to cause semen to fluoresce.[109] The Poliray™, high intensity LEDs and the Luxeon™ LED fared better in this regard.[109] LEDS lack versatility and are low powered but are by far the most affordable option amongst LEDs, lasers and ALSs.[106] ALSs are priced midway between LEDs and lasers, are high powered and very versatile if the particular model comes with multiple wavelengths.[106]

An increase in intensity and the number of wavelengths available is proportional to the chances of detecting evidence.[106] This is seen as motivation for investment in a high-powered ALS with multiple wavelengths, such as the one used here.

The SAPS also make use of another model of the Polilight® range; the Poliflare™ Plus 2. The Poliflare™ Plus 2 model offers many advantages to the PL500 model tested here. It consists of a set of individual lightweight torches each with one wavelength. This forfeits the fine tuning ability of the PL500 in favour of instantaneous use by means of one simple switch and no warming up period. The carry case for the Polilight® Flare Plus 2 serves as a charger which plugs into a mains or car supply. This means that the carry case remains stationary whilst charging the other torches not currently in use, allowing the examiner to use the individual torch of choice unencumbered. This makes it ideal not only for use on the scene, but also for use in the mortuary setting where the body or clothing can be manoeuvred with one hand whilst the torch is held in the other. As mentioned, the entire unit is much lighter and more portable than the PL500 model. It is considerably easier to use than the PL500 and great reductions in cost can be achieved by tailoring the choice of wavelengths purchased to the institution's specific needs; the entire set need not be purchased.

Raman spectroscopy has been suggested as a non-destructive confirmatory testing method for identifying and differentiating biological secretions at scenes of crime.[180] Raman spectroscopy has increased in popularity recently.[181-182] It is able to make use of a material's vibrational transitions to provide information with regards to the structure and properties of the questioned material.[87] Each sample produces a specific vibrational signature which goes towards identifying the sample.[87] This method has the potential to successfully identify a questioned stain as semen.[87] This technique has also been applied to the identification of fibres[183] and paint[184], amongst other things. It is a simple technique and does not require any reagents to perform the analysis.[87] Perhaps most noteworthy, is that the technique requires very little sample to examine – as low as several pictograms or femtolitres – and the sample is not destroyed.[87] Another positive aspect of this technique is that knowledge of Raman spectroscopy is not required in order to perform the analysis.[87] The method is well suited to the typically heterogeneous nature of bodily fluids.[87]

Furthermore, portable devices are already in existence.[185-186] Features such as mixing, dilution and substrate interference were not considered in the study by Virkler and Lednev (2009)[87] and further testing is needed to appreciate the real-life crime scene applicability of the method.

5.14 Overview

Despite the digital microscope performing statistically the best in this study and the Polilight® performing the worst, it must be kept in mind that each tool is best suited for different evidence types and this consideration is seen to bear more weight than generalized statistics. It is the researcher's recommendation that for an environment such as the PMLL, investment in a unit such as the Polilight® as well as the magnifying light would aid the investigation of many of the cases admitted there. Rape-homicides are the biggest application for the PMLL and additional time expenditure is justified for these cases. It is up to the discretion of other laboratories whether they are willing to conduct lengthy blind searches on each body that comes through their doors, but this is not practical in our setting.

An affordable and practical option may be to invest in one or two key wavelengths of the Poliflare™ Plus 2 unit (with several pairs of the appropriate goggles) along with a handheld illuminated magnifying glass. These alternatives offer cheaper as well as more portable options which would best suit the PMLL setting. These units would also be able to accompany the pathologist or specialist investigator to the scene, take up little space and are easy to use.

For the purposes of the PMLL, the best application of any of these technologies would be a system where the investigating officer and/or public prosecutor provides a guide of which evidence types would aid the investigation and help to streamline the process from our end. This is not to say that experience and professional opinions would be ignored or that potentially valuable evidence (unbeknownst to the investigating officer with a non-scientific background) would be overlooked, but it would greatly simplify the process if examiners were pointed in the right direction in order to make executive decisions as to how best to proceed with a specific case.

Considering the disruptions that these extensive examinations cause to the normal mortuary routine, it also seems best if the chosen tool(s) are only applied upon request by the investigator, or reserved to high profile cases, or perhaps certain types of cases – such as rape-homicides and hit-and-runs. Decisions would need to be made as to where these tools can add the most value as they appear thus far somewhat impractical for routine autopsy use.

Individuals from different professions assign different weight to different forms of evidence and case-outcome-affecting factors. Because only 17 responses to the questionnaire were obtained, significant weight is not placed on the replies given. The information attained here gave some interesting insights, as well as some predictable answers. The questions were straight forward (See Appendix D) and were not designed to deeply probe the issues surrounding trace evidence. The information attained here merely serves as a point of interest.

The expected bias towards DNA evidence as the strongest evidence type was demonstrated in the questionnaire results where more people felt that it would aid more cases than other trace evidence would. No one felt that either evidence type would have no use whatsoever in judicial proceedings. This demonstrates a baseline awareness and appreciation of the potential of trace evidence. Interestingly, more weight was given to biological evidence than fingerprints, even though fingerprints would offer a much stronger proof of contact, as opposed to biological samples which may be innocently and passively transferred. This perception may be due to the CSI effect,[178] but considering that all individuals interviewed were not ignorant of forensic realities, this is more likely due to a shift in reliance onto the relatively newer field of DNA profiling and the more statistically reliable identifications that are obtained.

Aside from the 1 individual who felt that the current judicial system was satisfactory in principle (with failures occurring in the application and management of said system), all respondents were dissatisfied with the current success rate of judicial proceedings. Some felt that the SAPS needed to be more involved and their investigations improved; others indicated that backlogs at laboratories were a major sticking point. Education and resource limitations were cited as areas for improvement. Some were wholly dissatisfied with the entire system, from the initial investigation and specialist analysis to prosecution. Cases need to be prioritized according to seriousness, with less time wasted on less grievous cases. Evidence collection at the crime scene was felt to be less than satisfactory due to carelessness or ignorance. One individual pointed out that improved technology alone will not improve case outcomes, and that passion, dedication and understanding of the fundamental issues – such as exhibit integrity – will go much further in improving conviction rates. Increased man-power is suggested as a solution. Better communication between all role players is also suggested. Ignorance with regards to the potential uses of technological aids is mentioned. Training is highlighted by most respondents as a key area for improvement.

It seems there are many areas needing improvement before satisfactory prosecution and conviction rates are achieved in South Africa and it is evident that technological improvements alone will not solve the problem. This is not to say that they do not have their place in the medico-legal investigation of death and crime, but other issues need to be addressed as well to achieve the desired result of justice for the victim.

When considering factors affecting decisions to pursue cases and subsequent convictions rates, lack of evidence and police inefficiencies were cited as the main problem areas. This suggests that the topic of research explored in this study is an important point of concern and tools which facilitate the detection and subsequent recovery of more evidence will be valuable to the administration of justice. A lack of understanding on the part of judges and prosecutors, as well as witnesses not attending court, were also mentioned as being counter-productive.

Most individuals feel that a substantial investment in evidence detection tools is justified and that only specialist investigators should be allowed to handle such equipment. This corroborates the researcher's belief that this type of equipment has value provided adequate training accompanies it.

Chapter 6: Conclusion

It was hypothesized that the use of technological aids would facilitate evidence detection from the bodies of victims of contact interpersonal violence. Emphasis was placed on the types of trace evidence recovered from the bodies and clothes of victims of interpersonal violence. It was hoped that this study would serve to enlighten the South African scientific community as to the value and viability of aspiring to international standards for the medico-legal investigation of death.

This study demonstrated the application of these and similar techniques to the medico-legal investigation of death in real-time, realistic field conditions. Other more structured studies may supply baseline information as to the capabilities of the individual tools and techniques, but this study gives insight into the application of technology in the real world. Other studies present ideals, but real practical issues have been encountered and assessed here and this study offers a guiding hand to make decisions for the real-life setting of a medico-legal mortuary.

This study was complicated by the fact that multiple parameters were being assessed concurrently. It is difficult to evaluate each variable without controlled studies and there is a limit with regards to other research for comparative purposes. In addition, the possibility for personal bias and over-interpretation to enter into the conclusions of this study must be kept in mind. This may dilute some of the conclusions reached but it was hoped that an interest would be sparked for future studies and further contemplation.

The world of forensics needs to apply tools which are simple to use, cost-effective, non-destructive and portable. The Polilight® is relatively expensive and best suited to detecting biological traces. The torch is lightweight and best for locating reflective particles and fluids. The magnifying lamp is useful for locating small particles that, although visible with the naked eye, are more easily detected at a slightly higher magnification; but a portable version would be more desirable. The digital microscope is cost-effective and best suited to examining specific particles or lesions, rather than locating them initially.

The hypothesis was found to be true to varying extents. It was found that these tools do have applicability in the medico-legal mortuary setting, but more rigorous studies would need to be done in order for a mortuary manager to be able to make informed decisions as to the justification of the expenditure of additional funds, time, training and effort at their specific institution. With strict training of specific designated individuals and a structured Standard Operating Procedure, the implementation of any one of these technologies would be viable in the mortuary setting, but further research would need to be conducted for a better appreciation of their true usefulness and capabilities.

No one technique stood out as the clear and obvious choice for application in the mortuary setting, or the crime scene or clinical setting. Each institution would need to delineate the evidence types that best serve their needs and make decisions as to the best investment to facilitate evidence recovery. There is no one technique that provides the perfect compromise between efficacy, ease of use and cost, and again, each institution would need to weigh these factors for themselves.

Even if none of these techniques explored here can be relied upon as a sole method of evidence detection, they can at least enhance certain evidence types and make them more readily noticeable to the examiner. None of the tools tested here were found to be wholly useless in evidence detection efforts; with each lending itself to certain situations and evidence types. Although no one tool could be considered ideal for application in the PMLL, similar equipment with slight variations as to cost, portability and ease of use may be able to provide the answer to our needs.

For the purposes of the PMLL, the best scenario would involve open communication and consultation with investigating officers and public prosecutors in order to decide how best to apply any of the tools studied here. Experience and knowledge from all parties would need to come together so that the most useful evidence can be recovered in the most efficient way.

The study also aimed to determine if the investigation of and investment in new technologies and techniques would aid the administration of justice. Without collecting and sending the evidence found through the system, it is difficult to fully appreciate the value that these and similar modalities could add to the medico-legal investigation of death. The laboratories and court system in South Africa experience significant delays, with most cases not going to court for several years. These considerations made it impractical to try and gauge the study's impact on the final case outcome; however desirable this may have been.

It was also envisioned that this thorough approach to body examination would potentiate a similar approach in the realm of clinical forensic medical examination. It was found that none of the tools tested were specifically reported as being contra-indicated for clinical use, but some were found to present obstacles. The Polilight® poses the most potential danger/discomfort for a living victim, whereas the magnifying lamp already finds use in the dermatological clinical setting.

The detection of the red paint chips, which were believed to have originated from the body bags, serves as an example of the inadvertent outcomes of the research. A serendipitous finding such as this can have a bigger impact on the way that medico-legal investigations are conducted at the PMLL and other mortuaries. An awareness of these kinds of contaminants should motivate individuals in managerial positions to rather invest in bags and other equipment made of inert materials. This incidental finding may go towards assisting us in the future in ways not originally expected at the start of the study.

Some knowledge can only be gained through experience and no amount of pre-reading will equip an examiner well enough to know how to handle every situation with which they are presented. What a tool advertises to be able to do and how it actually fits the needs of a certain institution can differ vastly, and validation studies such as this that test their real-world application are necessary before an informed decision can be made.

From the limited data gleaned in this study, it is the recommendation of the researcher that the PMLL, and similar institutions, invest in a unit such as the Poliflare® Plus 2 and a handheld illuminated magnifying glass. Once again, it is up to the discretion of management whether the ends justify the means and specific evidence analysis laboratories should be consulted to decide the best investment options.

Although the results of this study may be difficult to fully appreciate, it should be seen as a step in the right direction; with the aim of inspiring future studies and motivating South Africa to enter the world of modern forensic medical investigation. We need only grasp at what is within our reach.

Chapter 7: References

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Chapter 8: Appendices and Annexures

Appendix A: Protocol Advisory Notes

Because no one tool seemed to exactly fit the needs of the PMLL, a complete protocol cannot be drafted. However, listed below are some proposed advisory notes for the inclusion of such a tool into the mortuary protocol:

- Specialist individuals need to be entrusted with the task of using the chosen tool/s to limit the number of people requiring specialist training, increase the amount of experience gained by each investigator, and reduce the expectation that would otherwise be placed on the attending pathologist's already hectic task.
- The same individuals should be responsible for the care and safe-keeping of the equipment.
- When not in use, the equipment should be locked away in a designated area to avoid breakage or theft.
- The examination should ideally be conducted at the scene and the specialist individuals should be deployed to the crime scene to conduct the examination where possible.
- Failing this, the examination should be conducted when the body arrives at the mortuary, before refrigeration, so that condensation does not dislodge, obscure or confuse the evidence present.
- To limit the disruption to the autopsy process, the examinations should be conducted before the autopsy session but under the supervision of the attending pathologist so that findings are not brought under disrepute in court.
- The examination needs to be conducted in cooperation with the prosectors or other designated individuals so that the body can be manoeuvred and manipulated without disrupting the examiner.

- To further limit the disruption to the autopsy process, the examination should be conducted in a room separate to the main dissection hall.
- The room in which the examination is conducted needs to be well- and evenly lit to avoid shadows and increase the chance of evidence detection.
- Should an ALS be employed, the room needs to be able to be completely or near-completely blacked-out to increase the visibility of the fluorescence.
- Access to the examination room should be limited to avoid contamination from extraneous individuals and the potential loss of evidence from excessive airflow and traffic.
- Prosectors should be trained to remove clothing carefully for the preservation of physical evidence.
- A camera should be on hand to document all evidence detected before it is collected.
- Cases should be prioritized for examination. For example, examination may be more justified for rape/sexual assault, homicide and hit-and-run cases. This will go towards minimizing the disruption to the mortuary routine by only examining specified cases unless otherwise requested by an investigating officer or public prosecutor.
- Specific requests should be obtained from the investigating officer or public prosecutor as to whether a case needs to be examined and what evidence types are required for further analysis. This will make the examiner sensitive to evidence types that would be useful to the case rather than performing overwhelming blind searches.
- Examiners should still be trained to collect other evidence not specifically requested by the investigating officer or public prosecutor if they are of the opinion that it may have evidential value.

Appendix B: Practical Advice

Listed below are areas where further research could be conducted in order to enrich the findings of this study:

- The application of these and other tools at the crime scene.
- The application of these and other tools in the clinical setting.
- Controlled studies with known amounts of evidence to be able to compare each tool more reliably. This would go towards eliminating the issue associated with field cases where the initial potential amount of evidence to be found is unknown. ALSs have been compared, but literature on other modalities and their comparison against ALSs is limited.
- Studies whereby the evidence detected is collected, analysed and sent through the entire system would prove useful as they can be truly identified and their impact on the case outcome can be reviewed.
- Comparisons of evidence detection on human skin versus inert surfaces such as fabric.
- Comparisons of what is detected at the scene versus at the mortuary would aid in understanding issues of loss and contamination.
- Studies of the deposition hotspots would prove useful in perhaps narrowing down the large search area by informing investigators where first to start investigating.
- The effect of overlaying evidence types on detection of other potential underlying evidence, such as blood-covered items.
- Studies measuring the loss and dislodging of evidence with the removal of clothing prior to examination could be studied to aid institutions to decide which option would better suit their purposes.
- Studies comparing the amount of passive background DNA and evidence on individuals compared to that found on victims of violent altercations.

- Effects of washing the body or clothing prior to examination.
- Samples of the same fluid from different donors, as well as different samples from the same donor, all differ, and this heterogeneity may have unprecedented effects on the ability of detection methods to work effectively. This topic could also be explored to see if studies where only one individual's DNA is used are really able to be generalized to apply to all DNA.

Appendix C: Data Collection Sheet

DR #: ________/2012_ Sex: (1) Male ☐ (2) Female ☐

REF #:______________ Race: (1) White ☐ (2) Black ☐ (3) Coloured ☐ (4) Other☐

Cause of death:

(1) PVA ☐ (4) Strangulation (Manual) ☐ (7) Gagging ☐
(2) Assault (blunt) ☐ (5) Strangulation (Ligature) ☐ (8) Other ☐____________
(3) Assault (sharp) ☐ (6) Multiple Modalities ☐

Rape Suspected: (1) No ☐ (2) Yes ☐

History:

____

Clothing worn:

(1) Hat ☐ (5) Pants ☐ (9) Bra ☐ (13) Shoes ☐
(2) Coat ☐ (6) Shorts ☐ (10) Gloves ☐ (14) Jacket ☐
(3) Shirt ☐ (7) Skirt ☐ (11) Belt ☐ (15) Other ☐____
(4) Jersey ☐ (8) Underwear ☐ (12) Socks ☐ ____________________

Apparent trace evidence located:	**Seen with**			
	Torch	**Mag. Light**	**Digital Micro.**	**Polilight**
(1) Plant matter				
(2) Ground matter				
(3) Glass				
(4) Plastic				
(5) Fingerprint				
(6) Other imprint				
(7) Tattoos				
(8) Faeces				
(9) Insects				
(10) Paper				
(11) Hair/fibres				
(12) Paint				
(13) Semen				
(14) Urine				
(15) Saliva				
(16) Detergent Stains				
(17) Unknown fluid				
(18) Other				
(19)				

____

____

Appendix D: Questionnaire

Dear Participant,

I am a Masters student studying Medical Criminalistics in the Department of Forensic Medicine at the University of Pretoria.

You are invited to volunteer to participate in my research project on “The application of imaging technologies in the detection of trace evidence in forensic medical investigation”.

We would like you to complete a questionnaire. This will take about 15 minutes. This questionnaire poses no loss or benefit to yourself and as it is on a voluntary basis, no compensation for participation will be offered.

The purpose of the study is to determine the value of newer technologies in the detection of trace evidence on victims of interpersonal violence and the subsequent value of this evidence in judicial proceedings and the administration of justice. You are consenting to give your professional opinion regarding questions relating to trace evidence in the forensic context.

The Research Ethics Committee of the University of Pretoria, Faculty of Health Sciences granted written approval for this study. Please do not write your name or other personal details on the sheet as the results of the survey are to be kept entirely anonymous.

The implication of completing the questionnaire is that informed consent has been obtained from you. You are entitled to full access to the research protocol, should you wish to view it. Once you have completed and returned this form, your consent cannot be later revoked. Thus any information derived from your form may be used for e.g. publication, by the researchers.

We sincerely appreciate your help.

Yours truly,

Jeannie Cocks

I hereby indicate that I wish to participate in the afore-mentioned study and give consent for my answers to the questionnaire to be used at the researcher’s disposal.

Date: ___________

Profession/Capacity: ____________________

Years of experience: ____________________

1) If trace evidence potentially connecting a perpetrator to the victim (eg. soil, pollen, dust, gravel, paint chips, fibres, glass etc.) were recovered from the body/clothing of a victim of interpersonal violence as part of the medico-legal investigation, it would facilitate and strengthen the judicial proceedings.

In all cases	In most cases	In some cases	In no cases
☐	☐	☐	☐

2) If biological evidence potentially connecting a perpetrator to the victim (eg. semen, blood, urine, saliva etc) were recovered from the body/clothing of a victim of interpersonal violence as part of the medico-legal investigation, it would facilitate and strengthen the judicial proceedings.

In all cases	In most cases	In some cases	In no cases
☐	☐	☐	☐

3) If fingerprints were recovered from the body of a victim of interpersonal violence as part of the medico-legal investigation, it would facilitate and strengthen the judicial proceedings.

In all cases	In most cases	In some cases	In no cases
☐	☐	☐	☐

4) Technologies which prove useful in the detection of trace evidence in the medico-legal investigation of fatally injured persons in the mortuary setting will have the potential to be of value in the clinical forensic setting (i.e. examination of survivors of interpersonal violence).

In all cases	In most cases	In some cases	In no cases
☐	☐	☐	☐

5) If the application of technologies (eg. digital microscope, alternate light source etc.) proves useful in the detection of trace evidence in the medico-legal examination of victims of crime, such technological aids should be implemented as a routine protocol within the South African forensic setting.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

6) In your opinion, what could be done or changed to improve the prosecution and conviction of criminals in our country?

Nothing, I am satisfied with the current system ☐ Other ☐

If other, please specify:

____

____

____

____

7) What are the main factors compromising decisions to pursue cases?

Lack of evidence ☐ Police inefficiency ☐ No suspect ☐ Lab inefficiencies ☐ Other ☐

Other, please specify: ______________________________

8) What are the main factors influencing whether a case leads to a conviction?

Lack of evidence ☐ Police inefficiency ☐ No suspect ☐ Lab inefficiencies ☐ Other ☐

Other, please specify: ______________________________

9) How much additional capital investment into technologies which would improve trace evidence recovery would be justified?

0% ☐ 5% ☐ 10% ☐ 25% ☐ ≥50% ☐

10) Should these technologies be supplied to existing individuals in the investigation (i.e. the police) who are trained in evidence recovery or to separate specialist evidence recovery teams?

Existing Individuals ☐ Specialists ☐

-------Thank you for your time-------

Annexure A: Ethics Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee

10/05/2012

Number :	**S23/2012**
Title :	The Application of Imaging Technologies in the Detection of Trace Evidence in Forensic Medical Investigation
Investigator :	Jeannie Cocks, Department of Forensic Medicine, University of Pretoria (SUPERVISOR: Prof G Saayman)
Sponsor :	Research Fund and Capital Equipment Fund of the Department of Forensic Medicine, University of Pretoria
Study Degree:	**MSc – Medical Criminalistics**

This Student Protocol was reviewed by the Faculty of Health Sciences, Student Research Ethics Committee, University of Pretoria on 8/05/2012 and provisional approval herewith given, pending receipt of approval from the MSc. Committee.

Prof M J Bester	BSc (Chemistry and Biochemistry); BSc (Hons)(Biochemistry); MSc (Biochemistry); PhD (Medical Biochemistry)
Prof R Delport	(female)BA et Scien, B Curationis (Hons) (Intensive care Nursing), M Sc (Physiology), PhD (Medicine), M Ed Computer Assisted Education
Dr NK Likibi	MBB HM – (Representing Gauteng Department of Health) MPH
	Student Ethics Sub-Committee
Prof R S K Apatu	MBChB (Legon,UG); PhD (Cantab); PGDip International Research Ethics (UCT)
Mr S B Masombuka	BA (Communication Science) UNISA; Certificate in Health Research Ethics Course (B compliant cc)
Mrs N Briers	(female) BSc (Stell); BSc Hons (Pretoria); MSc (Pretoria); DHETP (Pretoria)
Prof M M Ehlers	(female) BSc (Agric) Microbiology (Pret); BSc (Agric) Hons Microbiology (Pret); MSc (Agric) Microbiology (Pret); PhD Microbiology (Pret); Post Doctoral Fellow (Pret)
Dr R Leech	(female) B.Art et Scien; BA Cur; BA (Hons); M (ECI); PhD Nursing Science
Dr S A S Olorunju	BSc (Hons). Stats (Ahmadu Bello University –Nigeria); MSc (Applied Statistics (UKC United Kingdom); PhD (Ahmadu Bello University – Nigeria)
Dr L Schoeman	CHAIRPERSON: (female) BPharm (North West); BAHons (Psychology)(Pretoria); PhD (KwaZulu-Natal); International Diploma in Research Ethics (UCT)
Dr R Sommers	**Vice-Chair** (Female) MBChB; M.Med (Int); MPhar.Med
Prof L Sykes	(female) BSc, BDS, MDent (Pros)

DR L SCHOEMAN; BPharm, BA Hons (Psy), PhD;
Dip. International Research Ethics
CHAIRPERSON of the Faculty of Health Sciences
Student Research Ethics Committee, University of Pretoria

DR R SOMMERS; MBChB; M.Med (Int); MPhar.Med.
VICE-CHAIR of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

012 354 1677 0866516047 deepeka.behari@up.ac.za http://www.healthethics-up.co.za
Private Bag X323, Arcadia, 0007 - 31 Bophelo Road, HW Snyman South Building, Level 2, Room 2.33, Gezina, Pretoria

Prof L M [illegible]	MBChB(Natal), FCS(SA)
Mrs M C Nzeku	(Female) BSc(NUL); MSc Biochem(UCL,UK)
Snr Sr J. Phatoli	(Female) BCur (Et.Al); BTech Oncology
Dr R Reynders	MBChB (Pret), FCPaed (CMSA) MRCPCH (Lon) Cert Med. Onc (CMSA)
Dr T Rossouw	(Female) MBChB.(cum laude); M.Phil (Applied Ethics) (cum laude), MPH (Biostatistics and Epidemiology (cum laude), D.Phil
Mr Y Sikweyiya	MPH (Umea University Umea, Sweden); Master Level Fellowship (Research Ethics) (Pretoria and UKZN); Post Grad. Diploma in Health Promotion (Unitra); BSc in Health Promotion (Unitra)
Dr L Schoeman	(Female) BPharm (NWU); BAHons (Psychology)(UP); PhD (UKZN); International Diploma in Research Ethics (UCT)
Dr R Sommers	**Vice-Chair** (Female) - MBChB; MMed (Int); MPharMed.
Prof T J P Swart	BChD, MSc (Odont), MChD (Oral Path), PGCHE
Prof C W van Staden	**Chairperson** - MBChB; MMed (Psych); MD; FCPsych; FTCL; UPLM; Dept of Psychiatry

Annexure B: MSc Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

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1908 - 2008

FACULTY OF HEALTH SCIENCES

SCHOOL OF MEDICINE

To: Prof Saayman

Student name	JEA Cocks	**Student number**	28044046
Name of study leader	G Saayman		
Department	Forensic Medicine		
Title of MSc	The application of imaging technologies in the detection of trace evidence in forensic meidcal investigation		
Date of FIRST submission March 2012	expand objectives; questionnaires according to discussions compare different clinical settings;discuss criteria of viability of study;MEMO received;NOT approved in current format		
April 2012	Minor changes as discussed in meeting; Add completion of TNM 800 on cover page ETHICS OUTSTANDING **PROVISIONALLY ACCEPTED**		
July 2012 (after July meeting)	Ethics approved **FINALLY ACCEPTED**		

Prof E Pretorius

Head: MSc Committee