FORENSIC DENTISTRY - BITE MARK DISTORTION

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THESIS

Submitted for

The Degree of Doctor of Dental Surgery

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Glasgow Dental Hospital and School

University of Glasgow, April 1998

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ACKNOWLEDGEMENTS

I am indebted to a number of people who have assisted me during the course of this work. Firstly, I should like to express my sincere gratitude to my adviser, Professor D G MacDonald, for his expertise, time and patience. My thanks are also due to Dr R Strang for his technical assistance in producing the graphs of the significant correlations and to Dr H. Gilmour for statistical advice.

I am grateful to Mr C Sanders for the production of some figures, to Mrs J. Hope who developed and printed the photographs and to Mr J. Davies for some of the illustrations. My thanks are due to Mrs J. McCaig who transcribed my work into print.

I should also like to thank the 20 subjects who facilitated the research, the staff of the department of Clinical Physics and Bio-engineering, Greater Glasgow Health Board where the extension arm with measurement frame was constructed and Mr M. Broad who produced the die stamp.

I am grateful to the staff of the library in Glasgow Dental Hospital and School and the library in the Department of Forensic Medicine and Science, University of Glasgow.

Finally, I owe a special thanks to my wife, sons and daughter for their support and understanding throughout the years of this work.

DECLARATION

This thesis is the original work of the author.

Douglas R. Sheasby, April 1998.

PREFACE

The work reported in this thesis was undertaken in the department of Oral Sciences, Glasgow Dental Hospital and School between October 1992 and March 1998.

The techniques used were specifically developed for this research. The application of the techniques described was conducted personally by the author. The production of the photographic prints was carried out by technical staff of the Department of Oral Sciences under the direct supervision of the author and his adviser.

Part of the work has been presented at the annual conference of the British Association for Forensic Odontology in November 1997 in a presentation entitled "Distortion in Bite Marks".

SUMMARY

The major challenge in forensic dentistry is the analysis of bite marks in human skin. A recurring difficulty in analysis arises from the distortion which is a variable feature of bite marks. Distortion may complicate or even preclude proper comparison of the bite mark and the causal dentition. Distortion may arise in a number of ways. The action of biting may produce tissue distortion and dynamic distortion. Evidence recording of the bite mark may produce posture distortion and photographic distortion. Ante and post mortem changes may also introduce distortion.

The present research initially consisted of a retrospective review of forensic bite mark cases analysed in Glasgow between 1971 and 1989. The review, reported in Chapter 2, demonstrated that the breast was the most commonly bitten anatomical location in females and that the quality of recording of individual tooth elements in the bite marks was variable; good quality elements formed the minority group.

Experimental research of human bite marks in human skin is, by its nature, difficult to conduct. Consequently, previous studies have mainly used experimental bite marks in animal skin or experimental bite marks in artificial media. One study in America recorded bite marks accurately in wax and established criteria which would require to be satisfied in bite mark cases. The retrospective review of bite mark cases found that bite marks which demonstrated good quality individual tooth elements formed the minority group and consequently the requirements for valid comparisons set by the American research were infrequently met in case work.

A particular forensic bite mark case in Liverpool demonstrated distortion of a bite mark in the female breast; the posture distortion was produced by varying the victim's arm position during evidence recording. The posture distortion percentage values were of the order of 25%. This case provided the stimulus to research posture distortion in the female breast. In addition, the relevance of the female breast as an anatomical site for study had been established in the retrospective review.

A preliminary study of two subjects was undertaken to quantify posture distortion in the female breast, to compare posture distortion in different breast sites and to study the influence of arm movement on posture distortion. The preliminary study is described in Chapter 3. As an alternative to experimental bites, a die stamp was designed with approximate dimensions of a human bite. Marks were made on different areas on the breast with the subject's arm in several positions. Dimensional changes were measured and expressed as percentage changes. The posture distortion percentage values of the preliminary study were similar to those in the Liverpool case. Therefore, the preliminary study was assessed as realistic in demonstrating posture distortion comparable to that in a forensic bite mark case.

The preliminary study produced general conclusions which provided the basis for further research. The initial stages of the main study, reported in Chapter 4, of 20 subjects of varying ages and anatomical proportions was undertaken to quantify posture distortion in the female breast, to compare posture distortion in multiple axes of four breast sites and to study the influence of arm movement on posture distortion. In addition, the main study assessed the influence of age, bust size, cup size and ptosis on posture distortion, The dimensions of the marks were recorded photographically and defined elements of the marks were digitised manually for computer analysis. The study showed that maximum posture distortion was mainly related to older subjects with increased ptosis and a larger cup size.

In view of the large volume of data, it was considered appropriate to concentrate initially on certain measurements from the left breast. The longest measurements in each axis reflected the major dimensions encountered in bite mark cases. In this way the main study produced six measurement tables of data. The analyses of the six sets of measurements are presented in Chapters 5, 6, 7 and 8. The analysis of the measurement tables commenced by studying the minimum and maximum posture distortion percentage values. The significance of age, bust size, cup size, ptosis and arm movement in relation to posture distortion in four axes was also assessed. Cup size was found to be the most frequent statistically significant factor; age and ptosis were often statistically significant and bust size was rarely significant. The most extensive arm movements were frequently significant compared to the least extensive arm movements.

It is believed that the data on posture distortion will make a contribution to forensic case work. If, in a bite mark case involving the female breast, it is found that there is a difference in dimensions between the suspect's dentition and the mark, it would be appropriate to verify whether the dimensional difference, expressed as a percentage change, came within the range of posture distortion values reported in this thesis. This would require to take account of the variable factors of age, bust size, cup size, ptosis and arm movement. It is felt that, at this time, it would be unwise to attempt to predict posture distortion in an individual case because of the difficulty in assessing all the variables involved. Furthermore, the influence of the variable factors would ideally require to be assessed by multi-variate analysis, a technique not undertaken in this research.

The main study researched posture distortion in the female breast. Clearly, the technique could be applied to other relevant anatomical sites which are potentially liable to posture distortion. In this way, a scientific database of posture distortion values and significant factors would be created.

Chapter 1

LITERATURE REVIEW

Chapter 1

LITERATURE REVIEW

1.1 INTRODUCTION

MacDonald (1974) defined a bite mark as "a mark caused by the teeth either alone or in combination with other mouth parts". Bite marks occur in skin, food and a miscellaneous group of inanimate materials. The research reported in this thesis is limited to human bite marks in human skin, in particular, the female breast.

A bite mark in skin is evidence of contact between the teeth, either alone or in combination with other mouth parts, and the skin. Consequently, a bite mark is produced by three contributory components - dentition/mouth parts, skin and the episode of contact. Each component is subject to variation as are the inter-relationships of the components of a particular bite mark.

1.2 DENTITION/MOUTH PARTS

The relevant dental anatomy consists of the arches, teeth, tongue and other mouth parts. Bite marks are normally produced by the anterior dentition and therefore it is appropriate to study the maxillary and mandibular arches and teeth inclusive of the second premolars.

1.2.1 Arches

There are a number of arch features which are important in bite mark analysis. The upper arch is normally larger and is composed of larger incisors and canines compared to the lower arch. The arch centre point is an orienting feature.

Arch size is usually expressed as the intercanine distance. Moorress (1959) recorded a mean maxillary intercuspid distance of 33.74 ± 2.52mm in 45 males. Rawson et al (1984a) recorded an average maxillary arch width of 32.3mm in 400 adults.

Arch shape is normally a U-shape and may vary to either a square or V-shape.

1.2.2 Teeth

There are a number of individual tooth features which are important in bite mark analysis. The presence or absence of a tooth is important; although, the apparent absence of a tooth in a bite mark may be false - the tooth could be present but not produce a mark.

The location of the mesial and distal incisal angles of incisors determines their width and centre point. The location of the cusps of canines, the buccal and palatal cusps of upper premolars and the buccal and lingual cusps of lower premolars are important individual tooth features.

The character of the incisal edges and cusps may be affected by various factors. The functional aspects of occlusion and malocclusion produce incisal and cuspal characteristics. The edges of newly erupted upper and lower permanent incisors show three small tubercles which are worn level with occlusion (Scott and Symons, 1972). However, anterior teeth which are out of occlusion may retain the notches indefinitely, for example, Angle Class II Division I malocclusion. Attrition of incisors and canines is no longer considered a prerequisite of age but is common in much younger groups of both modern and primitive societies (Dahlberg, 1960). Fracture of incisors or canines may result in a deficiency in the incisal/cuspal level which may be represented as either a false absence or a faint element in the bite mark. Alternatively, a fracture may result in an angulation of the incisal edge or cusp which may be represented as a variation in the density of an element in the bite mark. Class IV restorations with a defective incisal cavo-surface angle, crowns with a wider labio/palatal or lingual dimension, prostheses, caries and developmental peg-shaped lateral incisors are further examples of variation in the character of the incisal edges and cusps.

The status (position) of a tooth may be expressed as displacement and/or rotation. Duguid and McKay (1981) concluded that tooth position was the most constant feature relative to an ideal arch; therefore, variation in tooth position was of greater statistical significance. The interproximal embrasures are important distinguishing features between the individual tooth features. The petechial haemorrhages, often seen in bite marks, which are associated with the interproximal embrasures provide incisor width information and a representation of the spacing of individual teeth.

Duguid and McKay (1981) concluded that embrasure intervals were more variable relative to an ideal arch; therefore, variation in embrasure interval was of less statistical significance.

1.2.3 Tongue and other mouth parts

The action of sucking produces a reduced intra-oral pressure which can traumatise capillaries in embouched tissue. The occurrence of sucking during biting may introduce dimensional change in the inter-relationships of the dental arch components due to obvious "tenting" of the bitten surface. The presence of a diffuse ovoid zone of bruising within the centre of a bite mark is indicative of sucking activity (Sopher, 1976 p139)

Sucking may be accompanied by tongue thrusting, in which case, the appropriate descriptive term is suckling (Harvey, 1976 pp107,128). The tongue is a muscular organ which can produce pressure marks in tissue held in the mouth. Tongue pressure marks are caused by a tongue thrusting action forcing the embouched tissue against the palatal and lingual surfaces of the anterior dentition and the anterior palate. The relevant anatomical features consist of the palatal/lingual tooth surfaces, gingival margins, interproximal embrasures and rugae. The resultant tongue pressure marks may demonstrate patterns of bruising attributable to specific anatomical features (MacDonald, 1974). The marks may be extremely accurate and detailed. The presence of a prosthesis is also reflected in tongue pressure marks; patterns of diffuse bruising may be due to pressure against a smooth acrylic base plate; by contrast, patterns of specific bruising may be due to pressure against a cobalt chrome skeleton or a fixed bridge.

Tongue pressure marks usually occur in cases of an assailant biting a victim. Consequently, when tongue pressure marks are observed in bite mark cases, it may be an indication of the circumstances of biting.

1.3 SKIN

The different skin areas of the body surface vary widely in structure and in the degree of development of certain features. Adaptations to varying external conditions take place and considerable change occurs with age (Garven, 1965). Skin, when fully developed, consists of an epidermis, a dermis and a hypodermis. The epidermis is a highly developed compound epithelium; this is a layer of keratinising stratified squamous epithelium which is avascular and consequently, minor injuries are relatively harmless. The dermis is a connective tissue layer with many special features; the blood vessels, lymphatic vessels and nerves of the skin are present in the dermis. The hypodermis (subcutaneous layer) extends from the lower surface of the dermis to the underlying structure - muscle, fascia, ligament or bone. In many areas the hypodermis is a layer of adipose tissue.

Skin is said to be a poor impression medium because it is not dimensionally stable and is not capable of reproducing detail. There are a number of histological and physiological features which have a contributory influence; in particular, these relate to age and anatomical location.

1.3.1 Age

Babies bruise easily; however, bruises in babies are sometimes difficult to see because of abundant subcutaneous fat.

According to Gresham (1986 p21) bite marks in children are often faint and difficult to see. An interesting feature of such bite marks is that the initial lesion may fade away to become visible a few months after injury. The likely explanation for this is that melanocytes tend to migrate slowly to the edges of wounds and they indicate their presence by absorbing ultraviolet light. The wounds can only be demonstrated by ultraviolet photography when a sufficient quantity of melanocytes has collected at the wound edges.

Important changes take place in the skin with ageing. In old age, the epidermis is very much thinned. The elastic fibre content of the dermis decreases with age; in old age, the dermis is relatively avascular and elastic fibres have very largely disappeared. The aged bruise easily due to poor collagen support of blood vessels and consequently, slight pressure can produce an extensive bruise.

In contrast to infants and old people, teenagers and adults bruise less easily (Harvey, 1976 p94; Gresham, 1986 p10).

1.3.2 Anatomical location

In certain anatomical locations the hypodermis binds the tissues above tightly to those below and consequently little movement between the two is possible, for example, nose, scalp, pinna of ear, finger pads, palms, sole and plantar surface of toes. In other locations, the two parts, skin and underlying tissues, slide on one another freely, for example, eyelids, penis and scrotum. Bruising develops more easily in soft, vascular, lax tissues such as the eyelids than in tough and less vascular ones such as the palm of the hand or the sole of the foot (Simpson and Knight, 1985). Laceration occurs more readily in sites where the skin is relatively fixed to unyielding bone such as the scalp (Gresham, 1986 p13).

The contour or shape of the body varies depending on the anatomical location. In effect the quantity of tissue available for biting varies in different body sites; the scalp is an example of minimal available tissue; the female breast is an example of maximum available tissue. Obesity increases the tissue available for biting. The quantity of tissue available for biting is important for two reasons, kinetic energy and "tenting". Soft tissue absorbs and dissipates the kinetic energy of biting to a greater extent than hard tissue. Consequently, skin overlying soft tissue will be subjected to significantly lower levels of pressure than skin overlying hard tissue. The ability to absorb energy is related to the quantity of soft tissue. When a quantity of soft tissue is available, this may produce "tenting" of the bitten tissue thereby introducing dimensional changes in the skin. Clearly, the quantity of tissue taken into the mouth is also subject to variation.

1.4 EPISODE OF CONTACT

The dynamics of the action of one human biting another are produced by an extensive number of component factors - force, pressure, time, relationship of mandible to maxilla, movement of victim, movement of assailant, nature of bite, mental status of victim and mental status of assailant. The factors are variable and inter-related and consequently, the dynamics are extremely complex.

1.4.1 Action of biting

The action of biting comprises force, pressure, time and the relationship of the mandible to the maxilla. The factors which constitute the action of biting vary considerably and are inter-related. It is conceivable that the total possible permutations could be calculated mathematically by altering each factor incrementally for a given set of values. The anticipated total variations would be very high; this finding would reflect the extent of the complexity of the action of biting.

The pressure exerted by the dentition on the skin varies considerably which is reflected in the degree of holding of the tissue. In this way, the phenomenon of "tissue fixation" counteracts the effects of distortion by preventing movement between teeth and tissue.

1.4.2 Movement of victim and/or assailant

The dynamics of movement involve variations in speed, acceleration and direction (angle of contact). The movement of the victim and/or assailant can range from static to extreme movement. The mental status of the victim and the assailant are the conditioning factors of movement. The range in movement is exemplified in certain cases; bite marks which are clearly defined and appear to have been inflicted slowly and deliberately with little movement, probably as part of a sexual act; by contrast, bite marks which are poorly defined as a result of extreme movement during a violent attack and/or defence.

1.4.3 Nature of bite

The nature of the action of biting can range from amorous to aggressive with concomitant bite mark severity (MacDonald, 1974). An amorous bite mark ("love bite") occurs during the sexual arousal of lovers. The mark is usually bruising caused by sucking and tongue pressure and perhaps by gentle nibbling with the anterior teeth. The mark is characterised by diffuse bruising in the centre; individual tooth marks are not a feature. By contrast, an aggressive bite mark is inflicted with the intention of causing pain. The marks relate mostly to teeth; the tooth marks usually form an ellipse leaving a central area relatively unmarked; alternatively, the tooth marks constitute scrape marks due to movement between teeth and tissue.

1.4.4 Mental status of victim

Bites are painful injuries and consequently the mental status of the victim is relevant to the episode of contact. When the victim is conscious and cerebral function is unaffected by other factors, the response to pain is either fight or flight; the resultant movement has an influence on the bite mark. Alternatively, the victim's mental status may be affected by sexual arousal, alcohol and/or drug intoxication; in these cerebral conditions, the pain threshold is elevated and consequently increased trauma is tolerated by the victim. When the victim is unconscious or dead, response is non-existent and consequently more extensive trauma is possible.

1.4.5 Mental status of assailant

The assailant's mental status may be affected by anger, sexual arousal, alcohol and/or drug intoxication and these cerebral conditions may further potentiate the assailant's actions.

1.4.6 Uniqueness

The range in the variation of the component factors and their inter-relationships is such that it is hypothesised that every episode of contact between the dentition/mouth parts and the skin is a unique event. At the present time there is no scientific evidence to support this hypothesis. The ability to reproduce a bite mark identically would depend on an identical episode of contact; in practical terms this is difficult to conceive. If the theory was proved, the concluding logic would state that every bite mark is unique for a particular episode of contact. However, this raises another theoretical statistical possibility, that different dentitions could produce identical marks. The view that a bite mark is not reproducible was expressed by Levine (1977).

In bite mark cases, variation in the episode of contact is illustrated in multiple bite marks, produced by a single dentition in one victim, which vary in appearance (Whittaker and MacDonald, 1989 pp111-112)

1.5 NATURE OF INJURY

The shape of a single bite mark is usually almost circular or oval. Occasionally, multiple bite marks are superimposed on one another which results in variation in bite mark shape. The occurrence of a variety of other injuries superimposed on a bite mark is a rare complicating factor.

The injuries in skin are caused by the surface anatomy of the teeth. The biting surface produces crush injuries. The angle between the biting surface and the long-axial surface causes damage due to marked flexion and extension of the skin as it is sharply deformed round the angle. The interproximal embrasure produces petechial haemorrhages due to skin stretching across the embrasure or skin being forced into the embrasure. In these various ways, teeth impress their shape and surface markings in skin. Due to its elastic nature, skin is capable of absorbing considerable kinetic energy prior to the level of pressure required to produce visible injury (Sopher, 1976 p138). At the time of injury, particular tooth mark indentations will be present; however, the passage of time results in a smoothing out of the tooth depressions due to the skin's ability to reconstitute its original contour.

There is a considerable range in the degree of injury observed in bite mark cases (MacDonald, 1974). The severity of the bite determines the degree of injury. The severity of the bite ranges from a minimal contact with the skin surface to extreme clenching of the skin; consequently, the degree of injury ranges from mild skin bruises to avulsion of the bitten part respectively (Sopher, 1976 pp 126-127; Whittaker and MacDonald, 1989 p109-110). The degree of injury may be directly related to the nature of the crime. Consequently, in bite mark cases, the forensic dentist should take account of the nature of the crime.

At the microscopic level, the tissue response to biting is characterised by evidence of polymorphs within a few hours; evidence of granulation tissue occurs within 24 to 48 hours (MacDonald, 1992). These findings are dependent on a circulation and blood pressure and consequently the histological findings have a contributory value when considering the time of injury relative to the time of death.

A number of general factors influence the skin's response to injury; age, anatomical location, sex - females bruise more readily than males and systemic disease - certain conditions increase the bleeding tendency, for example liver disease and various blood disorders (Sopher, 1976 p139). The inter-relationships of the degree of injury and the general factors result in bite marks which vary significantly in appearance and duration.

Bite marks usually occur in skin which is not covered by clothing. The presence of clothing reduces the degree of pressure on the skin. The effect can mask the details in the resultant mark and may even be responsible for the absence of particular tooth injuries, for example maxillary lateral incisor injuries may be absent; however, this finding should not necessarily be interpreted as indicative of absent lateral incisors (Sopher, 1976 p139). Clearly, the thickness of clothing is relevant; the thicker the clothing, the greater is the reduction in the degree of pressure on the skin.

Bite marks in skin are composed of one or more of the following injuries, bruise, abrasion and laceration (Sopher, 1976 p138; Gresham, 1986 p21).

1.5.1 Bruise

A bruise (contusion) is usually caused by contact with a blunt object (Gresham, 1986 p10). The pressure of the contact disrupts capillaries allowing extravasation of blood into the dermis; the surface may or may not be intact. Blood will spread along normal tissue planes from the injury and a coloured area develops. Due to the breakdown of haemoglobin, the colour changes through a spectrum of red, brown, purple, green and yellow in the first week after injury. Gravity may cause the bruise to change position.

According to Sopher (1976 p139), due to the diffusion of haemorrhage, a phenomenon which may persist post-mortem, the area of a bruise related to a particular tooth or portion thereof will be slightly larger than the surface area which caused the injury. Indeed, the shape of a bruise may or may not bear a good relation to the contour of the tooth. This process of diffusion is responsible for the fading or haziness of the bite mark with time and the subsequent loss of what otherwise may represent an area of specificity.

1.5.2 Abrasion

An abrasion is a superficial injury of the skin where the surface layer of epidermis is rubbed off either by a sliding force or by direct pressure (Gresham, 1986 pp11-12). According to Gresham, abrasions can be subdivided into scratches, grazes and imprint abrasions due to pressure. Scratches demonstrate heaping of epidermis at the finishing edge of the scratch. Grazes are a form of scratch produced by injury from a rough surface and the pattern of grazing will depend on the nature of the surface. Imprint or pressure abrasions are produced by localised pressure to the skin.

1.5.3 Laceration

A laceration involves the splitting of the full thickness of the skin by a blunt injury (Gresham, 1986 p13). According to Gresham, lacerations are often accompanied by bruising and abrasion of the wound edges.

1.6 BITE MARK OCCURRENCE

Bite marks occur in a variety of crimes against the person - assault, murder and rape. The crimes involve varying degrees of violence; assault and murder may also be sex-related. Bite marks are found on all anatomical sites. Over 40% of victims have more than one bite mark and many have bite marks on more than one part of the body (Vale and Noguchi, 1983). Consequently, when one bite mark is discovered, a complete body examination of the victim should be conducted. According to Vale and Noguchi (1983), in female victims, bite marks are most common on the breasts, arms and legs; in male victims, the arms and shoulders are the most common sites. The morbidity associated with significant bites is well recognised (Mann, 1977; Burton et al, 1981).

When the victim is a child, the crime is termed child abuse. Usually there is a very limited number of people who have the opportunity to abuse the child; the abuser is usually the biter (Levine, 1977). Rawson et al (1984b) reported an epidemic of biting activity in a selected group of children in care. There is a widespread perception that the incidence of non-accidental injury to children is increasing either in real terms or in increased reporting. The circumstances of biting vary in children. The usual occurrence is the abuser biting the child (Sopher, 1977). The occurrence of children biting other children during play has to be recognised as an innocent bite mark. Similarly, self-inflicted bite marks in mentally retarded children are innocent and are related to attention-seeking behaviour.

The circumstances of biting are variable in adults. The usual occurrence is the assailant biting the victim; the victim biting the assailant occurs infrequently. Rarely the victim has a self-inflicted bite mark - for example, when the victim's hand is forced into the victim's mouth to stifle screaming. Bite marks are not usually observed in cases of natural death; however, self-inflicted bite marks can occur, albeit extremely rarely, in two ways. Self-biting may be an emotional response to pain or a type of counter-irritation to alleviate pain, for example, myocardial ischaemia (Warnick et al, 1987). Self-biting is a type of self-destructive behaviour which has been described in individuals who are mentally retarded or psychologically disturbed (Altmeyer et al, 1985; Sobel and Perper, 1985). Most bite marks noted in a medicolegal death investigation are associated with violent death; consequently, self-inflicted bite marks are rarely seen in cases referred for medicolegal death investigation.

It is theoretically possible that bite marks on either the victim or the assailant have been caused by either the other party, self or a third party. Consequently, the practical application is to examine all suspect dentitions. In the case of self-inflicted bite marks, the location is the significant anatomical fact - is it physically possible for the bite mark to have been self-inflicted ?

In female victims, bite marks are most common on the breasts (Vale and Noguchi, 1983). Consequently, the research reported in this thesis is limited to this anatomical site.

1.7 FEMALE BREAST ANATOMY

In most instances the breast attachment extends from the second to the sixth rib and from the sternum to the outer axillary line (Figure 1.1). The mammary tissue lies directly over pectoralis major and is separated from the outer fascia by a deep layer of adipose tissue, which is continuous with the fatty stroma of the gland tissue.

The centre of the dome-shaped fully developed breast in the adult woman is marked by the areola, a circular pigmented area of skin with a rougher surface due to large modified sebaceous glands. There are smooth muscle bundles, circular and radial, which extend out into the breast skin. Elastic fibres are numerous but less than in the nipple.

The nipple is a dome-shaped projection from the centre of the areola, a few millimetres above the breast, which carries along its central axis the 15-20 lactiferous ducts. The nipple is covered by pigmented wrinkled skin. There are numerous circular and longitudinal smooth muscle bands which can affect the shape of the nipple. There are many thick elastic fibres. Stimulation of the smooth muscle results in erection of the nipple.

The breast has a rich blood flow supply and an extensive network of lymphatic vessels which drain the tissue.

The size of the female breast is very variable (Netter, 1977). The subcutaneous texture and resilience of the breast contribute significantly to the extensive range of variability in the appearance of bite marks in the female breast.

1.7.1. Ptosis

The term ptosis is used to describe sagging or drooping of the breast based on age changes associated with the breakdown of fibrous connective tissue. According to the relationship of the nipple to the submammary fold, three degrees of ptosis are described (Figure 1.2). First-degree or minor ptosis - the nipple lies at the level of the submammary fold, above the lower contour of the gland. Second-degree or moderate ptosis - the nipple lies below the level of the fold but remains above the lower contour of the breast. Third-degree or major ptosis - the nipple lies below the fold level and at the lower contour of the breast.

Rawson and Brooks (1984) suggested a summary system of describing and delineating the variations of breast morphology (Figure 1.2)

I. Adolescent

II. Pubertal

III. Adult - Developing

Mature

Ptotic - Class 1

- Class 2

- Class 3

IV. Pregnancy - Lactation

V. Anomalies - Micromastia

- Macromastia

- Pathology - Tumours

In addition, breast morphology can be altered by the plastic surgery techniques of augmentation and reduction.

The age of the individual determines the shape, texture and resilience of the breast. The breasts of young females vary greatly from old females, especially those who have had several children and breast fed them.

1.8 BITE MARK ANALYSIS ACCEPTANCE

The first bite mark investigation to appear in the literature was in 1874 (Skrzeezkas, 1874). Much of the initial research was conducted in Scandinavia. The first significant case in Britain was in 1968 (Harvey et al, 1968) and in America four years later (Luntz and Luntz, 1973 pp157-162). The science of comparing bite marks in the skin of victims to the dentition of assailants has had a long and interesting history. The problem of admitting new scientific techniques into criminal cases is well recognised.

In Britain, the acceptance of bite mark analysis was established in 1968. In H.M. Advocate v Hay (Harvey et al, 1968), Lord Grant directed the jury thus: "Forensic odontology is a relatively new science but there must, of course, always be a first time for everything. The law must keep pace with science. I think it usually lags a little behind, but it does progress as scientific knowledge advances itself." Butler (1973) stressed the value of the bite mark evidence. The continued acceptance of bite mark analysis has been the responsibility of a limited number of experienced forensic dentists. This is reflected in the absence of contentious cases reported in the scientific or legal literature in Britain.

In America, most forensic dentists support the current state of the art; however, there are those who suggest re-evaluating the technique of bite mark analysis (Aksu and Gobetti, 1996). A review of trial transcripts reveals that distortion and the interpretation of distortion are the main factors in contentious cases (Rawson et al, 1986b). In perhaps the most compelling article on the legal implications of bite mark evidence, Hale (1978) questioned both the reliability of bite mark comparisons and the general acceptance of bite marks in the scientific community. Hale suggested that bite mark evidence should be excluded from the courtroom because of the lack of scientific reliability and the highly prejudicial nature of the evidence with the possibility of the failure of bite mark evidence according to the Frye Standard (Frye v United States, 1923). The Frye case established guidelines for the admissibility of scientific evidence related to new techniques. Therefore, in order to satisfy the Frye Standard, the scientific principle must be recognisable, the principle must be sufficiently established and the principle must have gained acceptance in the field to which it belongs (Whatmough and Nuckles, 1992). Neufeld and Colman (1990) stated that in order to be admitted as evidence, a forensic test should satisfy three criteria - the underlying scientific theory must be considered valid by the scientific community, the technique itself must be known to be reliable and the technique must be shown to have been properly applied in the particular case.

Various techniques for the actual comparison of the mark left in skin to the dentition have been described in court and legal decisions suggest acceptance of the procedures used (Levine, 1982 p121). However, of the techniques used, some have gained more acceptance than others which is partly due to certain legal decisions (Frye v United States, 1923, California v Kelly, 1976). Using the rationale of the Frye and Kelly precedents, the admission of bite mark evidence has been based on assessing the weight of the evidence rather than the admissibility of the bite mark evidence itself (Beckstead et al, 1979). The development of bite mark analysis has led to its acceptance by the scientific and legal communities (Levine, 1982 p113; Whatmough and Nuckles, 1992). In America by 1986, 192 cases had been cited in the legal literature and there were no references in the scientific or legal literature to a case in which bite mark testimony had not been allowed.

The American Board of Forensic Odontology established formal guidelines to aid in the handling of bite mark evidence in 1984 (American Board of Forensic Odontology, Inc, 1986). Subsequently, the American Academy of Forensic Sciences and the American Board of Forensic Odontology have studied and rationalised the major concerns in bite mark analysis and testimony. Those items considered most important for the development of scientifically founded standards are - uniqueness, consistency and accuracy in matching; methods for evidence collection and analysis; classification of tissue; analysis of distorted marks and expertise of the forensic dentist as demonstrated by certification and experience.

In 1997 the American Society of Forensic Odontology published the American Board of Forensic Odontology Guidelines and Standards for forensic dentistry; the sections related to bite marks established methods for collection of bite mark evidence, analysis and relevant terminology (American Society of Forensic Odontology, 1997).

1.9 KEY PRINCIPLES OF BITE MARK ANALYSIS

Uniqueness

The unique nature of the human dentition was confirmed by Rawson et al (1984a). Establishment of this fact has allowed forensic dentists to concentrate on determining the match between a dentition and the mark in skin.

Distortion

Some degree of distortion is present in all bite marks (Rawson et al, 1986b)

Representation of Uniqueness

It can be safely stated that if the correlation is high between the features of a dentition and a bite mark, then there can be an assurance that no other dentition could have caused the mark. (Rawson et al, 1984a)

Interpretation of Uniqueness

This is the focal point of bite mark analysis

1.9.1 Uniqueness

Historically, the general accepted view had been that the human dentition was unique, except perhaps in identical twins. However, Sognnaes et al (1982) demonstrated that young adult monozygotic twins were not dentally identical. There had been a lack of a scientific base of statistics to confirm the unique nature of the human dentition until confirmation by Rawson et al in 1984(a). The research was conducted on the upper and lower incisors and canines; each of the 12 teeth had six possible positions - buccal, lingual, mesial, distal, mesial rotation and distal rotation. The questions focused on the probability of different individuals having 12 teeth in matching positions. The statistical basis was determined from 1,200 bites from various parts of America. Each bite was recorded in wax 1mm thick which was coated on each side of hard cardboard 1mm thick. The bite was registered in protrusion such that the incisal edges of the six maxillary and six mandibular anterior teeth would be recorded to the maximum limited depth. The bite marks in wax were radiographed and the position of each tooth was recorded to allow ± 1mm centre point variation and ± 5° angle variation. The sample bites were structured to be representative of the general population. The actual number of positions that each tooth could occupy was determined; therefore the mathematics of probability became factual determinations. The actual total probabilities were calculated by multiplying the individual probabilities. The total positions of 12 teeth were calculated to be 1.36×10^{26}. The world population is approximately 5×10^{9}. In this way, Rawson proved mathematically that it would only require an accurate match of five teeth in a bite mark case to have confidence that no other dentition would be capable of producing the same mark. Therefore, the concordance of eight specific tooth marks to eight specific teeth would very safely be considered as characteristic or unique for a single person. The unique nature of the human dentition was confirmed.

Rawson's research was a study of the individuality of the human dentition by the use of a precise registration of that dentition into wax. The technique was appropriate for calculations of individuality as well as bite mark cases if there was a bite mark in skin of sufficient quality to permit accurate measurements within ± 1mm centre point variation and ± 5° angle variation.

This mathematical evaluation of a general population sample demonstrated the uniqueness of the human dentition beyond any reasonable doubt. Therefore, statements about individuality are now underwritten by scientific fact and consequently a bite mark represents evidence of the dentition of an individual during a potentially unique episode of contact with the skin. The problem of uniqueness has been superseded by the problem of whether there is a representation of that uniqueness in the component elements of the bite mark.

1.9.2 Representation of uniqueness

The registration of a dentition in an impression material without movement during the procedure enabled accurate measurements to be recorded and used for statistical analysis. Rawson's experimental bite mark contrasts markedly with the distortion usually observed in bite mark cases. The representation of the uniqueness of an individual dentition is the problem when determining the match between the bite mark and the dentition. According to Rawson, if the correlation was high between the mark and the dentition, then there could be an assurance that no other dentition could have caused the mark and that assurance could be justified as long as the individual tooth marks were within ± 1mm of centre point and ± 5° angle variation of each individual tooth; these measurements being within the limits of actual observation. However, the validity of Rawson's criteria in bite mark cases remains to be determined. Indeed, Rawson et al (1984a) stated: " The direction of the future will be to test the observational limits and to develop a better understanding of the distortion that is often seen in actual bite mark cases."

1.9.3 Interpretation of representation

The current major concern in bite mark analysis is the interpretation of the representation of uniqueness. Interpretation of the representation of the dentition in the bite mark is the focal point of bite mark analysis. The key question is whether the degree of correlation between the bite mark and the dentition can be determined reliably (Rawson et al, 1986a). Few experimental studies have been carried out to determine the reliability of comparison techniques on bite marks in skin. One study demonstrated that the dentition which produced test bites in wax was easily recognised with a high degree of reliability by forensic dentists and that experimental bite marks produced in non-vital pig skin demonstrated a much lower degree of reliability by forensic dentists determining the causal dentition (Whittaker, 1975). Similarly, experimental bite marks produced in vital dog skin without movement demonstrated a low degree of reliability by forensic dentists in being able to determine the dentition causing the mark (Rawson et al, 1986a). Dinkel (1974) stressed the need for further research in bite mark comparison techniques.

The Bite Mark Guidelines Committee of the American Board of Forensic Odontology reported to the Odontology Section of the American Academy of Forensic Sciences (American Board of Forensic Odontology, Inc, 1986) a system for the evaluation of bite marks in human skin. As part of the guidelines, the Guidelines Committee formulated a system of scoring each bite mark according to the overall arch size and shape, tooth positions and morphology. The scoring system was developed with the basic premise that unusual features were weighted compared with usual features. Consequently, an unusual tooth in an unusual position had a very high evidence value which was reflected in the scoring system (Figure 1.3). Rawson et al (1986a) concluded that the American Board of Forensic Odontology scoring system demonstrated a method of evaluation that produced a high degree of reliability among forensic dentists. Additionally, it demonstrated the ability to discriminate between different degrees of match - high scores produced a high confidence level that there was a match which could not have been produced by another dentition. This approach to the interpretation of bite marks formalised opinions which had been expressed by forensic dentists previously. Ström (1963) considered details more important than numbers of teeth in a bite mark, and emphasised the need to search for characteristic details of the suspect's teeth which may be reproduced in the bite mark; the importance of characteristic details was also emphasised by Keiser-Nielson (1967). Dinkel (1974) stated that there was no specific number of points of comparison required to make a bite mark identification.

Furthermore, Rawson et al (1986a) stated that if the bite mark was analysed by a group of forensic dentists and there was a corresponding high degree of consistency, then there was an extremely high confidence level in the conclusion of identity. Similarly, Ström (1963), Ligthelm and de Wet (1983) stated that there was a great strength in certainty if a positive identification was confirmed by more than one forensic dentist.

1.9.4 Distortion - general principles

Distortion complicates the process of comparing a bite mark to a dentition. A review of trial transcripts reveals that distortion and the interpretation of distortion are the main factors in contentious cases (Rawson et al, 1986b). The term distortion is defined thus (Chambers, 1989) -

Distortion - a twisting awry: deformation without breaking: crookedness.

According to Bernstein (1985), most references that deal with the technical handling of bite marks specify the recording of accurate measurements and the elimination of distortion so that the size of the bite mark can be compared to the size of the suspect's dental arch. The American Board of Forensic Odontology, attempting to ensure scientific validity and establish uniformity in bite mark analysis incorporated these considerations in their guidelines. However, some degree of distortion is present in all bite marks and may be produced by a variety of factors (DeVore, 1971; Barbanel and Evans, 1974; Levine, 1977; Rawson et al, 1986b). Consequently, an exact match in arch size is fortuitous and unpredictable, questioning the significance of this criterion; clearly, exact superimposition is only possible in bite marks exhibiting minimal distortion. The objective of accurate reproduction of the bite mark must be considered in perspective. The intention is not to produce exact superimposition but rather to preserve maximum visual information and reduce additional error in an already unpredictably distorted finding. However, this is not possible in every case and inability to control additional distortion may not necessarily invalidate bite mark comparison (Bernstein, 1985).

The degree of distortion present in a bite mark is variable and affects arch size and shape. Clearly, size-matching techniques are only applicable to bite marks exhibiting minimal distortion. The incidence of discrete morphological points of comparison or unique features in a bite mark are the most significant criteria in bite mark analysis. This is due to their relative immunity to distortion; the dimensions of unique features are of the order of <5mm which are proportionately less affected by distortion compared with an intercanine distance of 34mm. As the degree of distortion increases, bite mark analysis relies exclusively on unique features.

Distortion can be classified into four types, which in this thesis will be described as tissue distortion, dynamic distortion, posture distortion and photographic distortion. A bite mark may demonstrate more than one type of distortion. Tissue distortion and dynamic distortion are complex and unpredictable phenomena which are closely related because of their simultaneous occurrence during the episode of contact between the dentition and the skin. Posture distortion and photographic distortion occur during evidence recording and consequently provide an additional element of distortion superimposed on tissue distortion and dynamic distortion.

1.9.5 Tissue distortion

Tissue distortion is caused by the nature of skin (Barbanel and Evans, 1974; Rawson and Brooks, 1984). Tissue distortion arises during the episode of contact between the dentition and the skin. Skin is an elastic medium capable of distortion due to pressure and reconstituting its original contour when the pressure is removed. Skin tension, due to elastic fibres in the dermis, varies depending on age and anatomical location. The phenomenon of stretching and relaxing constitutes the nature of skin which produces a variable degree of tissue distortion in all bite marks. Tissue distortion can also arise due to oedema produced in response to biting. The quantity of tissue available for biting is also a contributory factor in tissue distortion. When a quantity of tissue is taken into the mouth, this may produce "tenting" of the tissue which results in dimensional changes in the skin.

1.9.6 Dynamic distortion

Dynamic distortion is produced by the dynamics of the action of biting (Rawson, 1982). Bite marks are produced during varying degrees of movement by the assailant and/or the victim thereby creating a dynamic event which is itself unique. The dynamic event is composed of multiple component movements by the assailant and/or the victim which result in an episode of contact between the dentition and the skin. Consequently, it is conceivable that every episode of contact is a unique event.

Analysis of the uniqueness of the event is limited to the resultant bite mark and the dentition; clearly the dynamics cannot be recreated for analytical purposes and the significance of this omission should be noted and accounted for during bite mark analysis. West and Friar (1989) unsuccessfully attempted to demonstrate the dynamics of biting using a video camcorder.

The dynamic event can range from static to extreme movement. Bite marks produced statically will demonstrate no dynamic distortion. Bite marks produced in the range of dynamics will demonstrate dynamic distortion in proportion to the degree of movement. Consequently, a dentition can produce bite marks which exhibit variations in appearance by varying the degree of movement. This phenomenon is illustrated in cases of multiple bite marks produced by a single dentition in one victim; the bite marks vary in appearance due to the unique dynamics of each biting episode. Multiple bite marks produce a particular opportunity to study and interpret the dynamics of the action of biting. With the exception of location and dynamics. all aetiological factors are constant in multiple bite marks. Assuming the influence of different location can be accounted for, dynamics remain the only variable in multiple bite marks. Consequently, the influence of dynamics is illustrated by comparing the different marks in a multiple bite mark case.

1.9.7 Posture distortion

During evidence recording, failure to reconstruct the victim's body position at the time of biting produces posture distortion. The degree of posture distortion depends on the variation in body position and the anatomical location. Posture distortion is proportional to the variation in body position; the greater the difference in body position between the time of biting and evidence recording, the greater the degree of posture distortion. Different anatomical locations potentially demonstrate varying degrees of posture distortion. The most significant posture distortion is observed in a limb depending on the degree of flexion and extension and in the female breast depending on the arm position and body position. Posture distortion occurs, to a lesser extent, in the torso related to limb position and in the neck related to head position. Posture distortion is not a significant factor in the skin of the face and the ear. In order to minimise posture distortion during photography, it is necessary to attempt to reconstruct the victim's body position at the time of biting because of the possible alteration in arch morphology due to skin stretching and relaxing (DeVore, 1971). Clearly this ideal is not always possible and if not, it is suggested that bite marks are photographed in a range of positional possibilities (Bernstein, 1985). Reconstruction of the victim's known body position at the time of biting or the reconstruction of a range of positional possibilities is most applicable to the live victim. In cases involving a dead victim, the body position is unknown and the reconstruction of a range of body positions is not so readily achieved. Therefore, the potential occurrence of posture distortion may be a more significant factor in dead victims.

Experience has taught forensic dentists to take account of posture distortion. The development of this expertise can be illustrated by comparing the following views. In 1971, DeVore stated that, when the victim's body position at the time of biting could not be determined, photographic superimposition assessing size comparison was meaningless. In 1985, Bernstein stated that technical infraction in processing and recording bite marks, though serious, need not automatically preclude the analysis. The Bite Mark Guidelines Committee of the American Board of Forensic Odontology, in a workshop at the 1984 Annual American Academy of Forensic Sciences meeting, collected cases that demonstrated significant disparity between the size of the arch of a known perpetrator and the bite mark produced as a result of elasticity or repositioning of the skin. Bernstein (1985) referred to a case in which the size of the bite mark was unreliably recorded, making size-matching between the suspect's dental arch and the victim's injury questionable. The case involved a known perpetrator; all photographic measurements were recorded with acceptable techniques to reveal a size discrepancy between the dentition and the bite mark due to skin elasticity. The wound was inflicted with the arm in flexion and photographed with the arm extended. The weight of the conclusions was lessened by these problems but the impartial handling of the evidence and the explanation of the discrepancies offered credibility to the analysis.

1.9.8 Photographic distortion

Photographic distortion is produced by the photographic method of recording the bite mark (Stimson, 1982). Photographic distortion arises as a result of the influence of the angle of the film to the mark and body curvature.

The ideal photographic angle is 90° - the camera is perpendicular to the centre of the bite mark (Rawson et al, 1986b). This angle produces parallelism between the film plane and the bite mark plane and consequently photographic distortion is insignificant. Variation from the perpendicular will produce photographic distortion in proportion to the extent of the variation. In effect, moving the camera to one side or the other of the bite mark creates photographic parallax. The American Board of Forensic Odontology Bite Mark Guidelines Committee (Rawson et al, 1986b) suggested that a circular scale should be included in photographs, to permit accurate calculations of the photographic angle and to allow correction for any distortion caused by improper angulation. If the roundness of the circular scale was re-established in the superimposition process, then the photographic distortion in the bite mark was also corrected. This suggestion resulted in the development of the bite mark standard reference scale - ABFO No.2 (Hyzer and Krauss, 1988). The inner edges of the scale each measure 80mm. The three circles each measure 20mm in diameter. An example of a similar scale is illustrated in Figure 1.4. The plane of the scale should be as closely coincident with the bite mark plane as possible. The objective is to ensure parallelism between the film plane and the bite mark/scale plane which are coincident.

According to Rawson et al (1986b), a curved body surface which allows visualisation of the entire bite mark has a surface angle too small to produce significant photographic distortion. This statement can only be made if the entire bite mark can be visualised from one direction. If the body curvature is so great as to obscure part of the bite mark, then the surface angle is large enough to cause significant photographic distortion and multiple photographs would have to be taken.

1.10 BITE MARK ANALYSIS TECHNIQUES

The first recorded technique of bite mark analysis was called "odontoscopy"" and was developed by Sörup in 1924 (Ström, 1963). Subsequently, numerous other techniques have been developed. There is no single technique for the analysis of bite marks. The technique used by a forensic dentist will depend on personal preference and ability to accommodate a particular format (Sopher 1976, p126).

The collection of evidence in a bite mark case comprises photographic techniques to record the bite mark and impression techniques to record the suspect's dentition. The bite mark is recorded by scaled photographs; the suspect's dentition is recorded by impressions which are poured as dental stone casts (American Board of Forensic Odontology, Inc, 1986). Bite marks which exhibit indentations may also be recorded by impressions and subsequent casts (Benson et al, 1988). Bite mark analysis is the comparison of the two pieces of evidence, namely the photographic record of the bite mark and the dental casts. The comparison consists of observing and interpreting points of comparability and incompatibility. Comparability is more difficult to observe and interpret than incompatibility. Many different methods have been utilised to accomplish a comparison; the problems in bite mark analysis are well recognised. Human skin is not an impression material and the episode of contact during biting is potentially a unique event. This combination of factors produces a marked variation in the quality of bite marks and the possibility that similar bite marks may have different causal dentitions. The variations in the quality of bite marks and in the mechanism of bite mark production determine the complex nature of bite mark analysis.

Various alternative photographic techniques and dental cast production methods have been reported in the literature. Toneline photography was described by Robinson and Wentzel (1982). Golden (1994) demonstrated the use of alternative light source illumination. McKinistry (1995) described two techniques to produce resin dental casts.

Farrell et al (1987) suggested that the validation of new comparison techniques was simplified by the significant time and scientific proof available for the fundamental techniques of comparison. Rigorous proofs were essential for the first case of comparison of fingerprints because it founded the science of comparison. Once the science of comparison was shown the be valid, it was much easier to demonstrate the validity of bite mark comparison because of reliance on established science.

New techniques reported in the literature are often demonstrations of new technology applied to the science of comparison (Beckstead et al, 1979). Scanning electron microscopy and computerised axial tomography have been utilised as adjuncts to normal comparison techniques. David (1986) described a case in which bite mark analysis was not entirely conclusive. Acrylic models of the tissue and the dentition were studied under scanning electron microscopy which revealed the presence of unusual three-dimensional characteristics. The high level of resolution and magnification of scanning electron microscopy quite clearly demonstrated three-dimensional characteristics not visible to the naked eye. Farrell et al (1987) described the application of computerised axial tomographic scanning to give a precise registration of the incisal edges of teeth for comparison purposes. However, the cost and availability of scanning electron microscopy and computerised axial tomography preclude their routine use in bite mark analysis.

Rawson et al (1979) described a technique to record experimental bite marks in human skin which was subsequently preserved A 0.25mm layer of 60% iodine solution was used as a radiopaque medium to cover the bite marks. The tissue was subjected to standard radiographic techniques for soft tissue visualisation. Rawson et al (1979) stated that contrast-enhanced radiography of preserved bite marks should be considered as an adjunct to standard photographic techniques in recording bite mark evidence. Similarly, Dorion (1987) described the transillumination of preserved bite mark specimens; a technique which has not found general favour. A method of preserving bite marks en bloc was described by Sweet and Bastien (1991).

Ultraviolet photography has also been utilised in bite mark analysis. Ultraviolet radiation is not reflected off the skin surface, but actually penetrates the surface (Krauss and Warlen, 1985; Krauss, 1986). Surgical scars under ultraviolet light demonstrated a significant increase in contrast; the images on the ultraviolet photographs appeared to represent healing collagen fibres. West et al (1987) attempted to standardise a technique for the ultraviolet photography of bite marks in human skin. The practical significance of ultraviolet photography was the achievement of higher resolution photographs months after the bite (Davies, 1986; David and Sobel, 1994). However, when considering the apparent benefits of ultraviolet photography, the phenomenon of the false positive must be taken into account. No detailed studies of possible false positive images created by ultraviolet photography have been published.

1.10.1 Nomenclature

Bite mark comparison techniques involve objective and subjective judgments by the forensic dentist. These judgments are complementary in nature with a varying proportion of objective and subjective input for any given decision. The terms are defined thus (Chambers, 1989) -

Objective - relating to or constituting an object: of the nature of, or belonging to, that which is presented to consciousness (opposed to subjective), exterior to the mind, self-existent, regarding or setting forth what is external, actual, practical, uncoloured by one's own sensation or emotions.

Subjective - relating to the subject: derived from, expressive of, existing in one's own consciousness.

The terms objective and subjective refer to fact and opinion respectively; consequently, the description of the science and art of bite mark analysis is appropriate. Research expands the scientific database which in turn conditions the opinions of forensic dentists. In this way, objective and subjective judgments are inextricably linked.

The terms metric and nonmetric analysis are also suitable for use in bite mark analysis nomenclature (Krauss, 1984). Metric analysis of bite mark evidence would be the absolute comparison using physical measurements of class and individual characteristics contained within the mark and a suspect's dentition. Nonmetric analysis of bite mark evidence would be the associative comparison of class and individual characteristics contained in the mark and a suspect's dentition. Thus, the terms metric and nonmetric analysis are synonymous with objective and subjective analysis respectively. The examination of the bite mark photographs involves objective and subjective judgments in relation to the quality of the bite mark. A high quality mark is analysed using mainly objective judgment with a minimal subjective input; as the quality of the mark diminishes, judgments progressively become mainly subjective. The examination of the dental casts involves essentially objective judgments with a minimal subjective input. Consequently, the proportion of objective and subjective judgments varies in different bite mark cases; however, it is not possible to eliminate the subjective element from bite mark analysis (Duguid and McKay, 1981).

1.10.2 Bite mark quality

Bite mark quality exhibits considerable variation which ranges from a collection of indistinct marks to an accurate reproduction of the dentition. The quality of a bite mark depends on the quality of the individual elements in the mark, the quantity of the individual elements in the mark, upper and lower arch reproduction and distortion incidence.

According to Sopher (1976 p136), the features inherent in a high quality bite mark are recent injury, tooth indentations capable of reproduction in an impression, definitive areas of contusion and the presence of specific peculiarities in the alignment or arrangement of the bite mark components. It is well recognised that unusual dental features produce distinctive bite marks.

The quality of a bite mark has a direct influence on the conclusions of bite mark analysis. A high quality bite mark affords the forensic dentist the opportunity to reach definitive conclusions. As the quality of the bite mark diminishes, conclusions correspondingly become less definitive.

1.10.3 Techniques

A bite mark is produced by the inter-relationships of an extensive number of variable aetiological factors. Consequently, it is logical to conduct bite mark analysis on a multi-discipline basis in order to reflect the aetiological range. This is undertaken by comparing the photographic record of the bite mark with the dental casts. The comparison of the two pieces of evidence consists of an indirect technique and various direct techniques.

The phenomenon of preconditioning - to prepare beforehand - is relevant to the technique of indirect comparison. The nature of subjective judgments render them liable to influence by preconditioning. Objective judgments, on the other hand, are relatively immune to preconditioning. Examination of the bite mark photographs depends on subjective judgments to a varying degree and therefore is potentially liable to preconditioning influences. However, dental cast examination is essentially objective by nature and consequently preconditioning is not important. Therefore, in order to minimise the preconditioning effect, the photographs are examined first. The first examination will, to a certain extent, precondition the forensic dentist when conducting the second examination which, in the case of the dental cast examination, is not important. Furthermore, a time lapse before cast examination will further reduce the preconditioning influence.

The technique of indirect comparison involves a number of stages which are conducted in a particular sequence - examination of bite mark photographs, examination of dental casts, repeat examination and finally comparative study. The bite mark photographs are examined and the characteristics of the mark are recorded. The forensic dentist is seeking an explanation for the overall mark and the individual elements in the mark. There are many questions posed at this stage - is the mark a bite mark? Is it of the size and shape usually seen ? Is it possible to orient the upper and lower arches ? Is it possible to identify the arch centre point and intercanine distance ? What are the characteristics of the individual elements in the mark ? The answers to these questions may indicate a potential dentition to the forensic dentist. The dental casts are examined and the characteristics of the dentition are recorded.

As a result of this procedure, the potential injuries which the dentition would cause will become apparent to the forensic dentist. The photograph and cast examinations are repeated on as many occasions as necessary; the rationale being that each examination produces an additional insight thereby maximising the total information recorded. The comparative study involves the interpretation of the examination findings from the two evidence sources. The relevant questions at this stage are - can the individual elements in the bite mark be accounted for by the individual teeth of the dentition? Are there individual elements in the bite mark which cannot be accounted for by the individual teeth of the dentition? The answers to these questions result in points of comparability and points of incompatibility respectively.

The technique of indirect comparison aims to create a sequential approach to data recording and a deductible method of comparative study. These disciplines will maximise the standard of results achieved by indirect comparison.

The techniques of direct comparison aim to provide a visual match between the bite mark photographs and the dental casts. The pressure-inducing incisal and cuspal surfaces of the dental casts are recorded life-size/magnified in such a manner that they may be superimposed on the life-size/magnified bite mark photograph. There are numerous superimposition methods of direct comparison. The dental casts are photographed at 90°; the negatives are printed as laterally reversed transparencies which are superimposed on to a positive print of the bite mark (Whittaker and MacDonald, 1989 pp117-118). A sheet of clear acetate is placed on the dental casts and the outline of the teeth is carefully traced thereby producing a transparency for direct overlay comparison (Luntz and Luntz, 1973 p154). West et al (1990) suggested that human skin was used as a template. Dailey (1991) described the use of a photocopy machine to produce a transparent overlay.

There are also non-superimposition methods of direct comparison. The biting edges of the dental casts are marked with printer's ink. Labial and occlusal photographs are labelled for comparison with the photographs of the bite mark (Furness, 1968). Rao and Souviron (1984) described a method of recording bite mark evidence as is done with fingerprinting.

Direct comparison is most applicable to bite marks exhibiting minimal distortion. However, in distorted marks, the laterally reversed transparent overlays can be utilised in a multiple sequence to demonstrate the individual elements of the arch.

The techniques of indirect comparison and direct comparison provide an appropriate analytical approach to the multi-factorial nature of bite mark aetiology. The combination of the techniques potentially provides for the complete analysis of the available evidence. In this way, the standard of the conclusions is maximised by combining the results of a multi-discipline technique of analysis.

1.11 BITE MARK ANALYSIS CONCLUSIONS

A trial is ideally a search for truth - to this end, the law permits qualified experts to testify and express opinions on matters in which they are professionally trained (Neufeld and Colman, 1990). As in other areas of forensic science, the forensic dentist bases his opinion on the findings from his examination and his ability.

The ability of the forensic dentist comprises a natural aptitude which has been trained and subsequently has gained experience. The "seeing" ability (Rawson et al, 1986a) and the powers of observation of the forensic dentist are variable and difficult to assess. Nordby (1992) distinguished seeing from observing thus: seeing is a physical state, a photochemical excitation that produces a neurological experience; observing is an experience enriched by knowledge, beliefs, values, theoretical commitments, and the goals or purposes for looking in the first place. The forensic dentist is confronted with the problem of interpretation of the evidence. Nordby (1992) also distinguished between observation and interpretation. Observation involves implicit reasoning, and is instant; it is a mental experience. Interpretation involves explicit reasoning and deliberate thinking. Objective judgments exhibit least variation between examiners, whereas subjective judgments exhibit greatest variation. The training of forensic dentists lacks formal structure. Experience is assessed in terms of the amount and the type of case work. It is generally accepted that two forensic dentists operating independently provide invaluable corroborative opinion.

The opinions of the forensic dentist can be classified into three categories of conclusions - exclusion of suspect, inclusion of suspect and limited conclusion. Within the categories of exclusion and inclusion there exists a range of conclusions.

Dinkel (1974) suggested a classification similar to the conclusions reached in other forensic disciplines - positive identification, positive elimination, possible identification, possible elimination and inability to reach a conclusion. Sopher (1976 p140) emphasised the inherent difficulties in the inclusion category.

1.11.1 Exclusion of suspect

Previously it was thought that bite mark comparison was of greater assistance as an exclusion process rather than an inclusion process (Ström, 1963; Gustafson, 1966 p161; Dinkel, 1974; Vale et al, 1976). However, the development of bite mark analysis has enabled forensic dentists to make significant progress in the contribution of the inclusion process. Certainly the exclusion of a suspect from consideration as having produced the bite mark is the easier conclusion to reach. Nevertheless, it represents a vital contribution because it redirects the search for the suspect.

1.11.2 Inclusion of suspect

According to Sopher (1976 p140) the inclusion of a suspect depends on how specific the points of comparison are that the suspect produced the bite mark. The specificity of the comparison encompasses the most difficult and controversial area in forensic dentistry. The problem of specificity in bite mark analysis results from the lack of scientific data for comparison. Classified bite mark characteristics on large sections of the population are unavailable (Aitken and MacDonald, 1979). Therefore, an absolute scientific estimation of specificity regarding the particular bite mark/suspect comparison is not possible.

The spectrum of results of bite mark comparison extends incrementally from a match through to no match. In view of specificity of comparison, the forensic dentist may experience difficulty in assessing the degree of probability when expressing his formal opinion - for example, when the results of bite mark comparison indicate a match between the bite mark and the suspect's dentition - how can the forensic dentist be certain that no other individual could have produced the bite mark ? The influence of specificity of comparison is maximised in bite mark cases with only subjective interpretation of the points of comparison. The forensic dentist attempts to determine the points of comparability between the bite mark and the casts in an effort to enhance the specificity of the comparison procedure. Similarly, the absence of points of incompatibility between the bite mark and the casts adds weight to the comparison procedure. The weight of evidence conditions the conclusions reached by the forensic dentist. Since the forensic dentist cannot precisely state the probability or degree of certainty inherent in his conclusions, it is important to clarify the opinion by indicating the weakness or strength of the evidence (Sopher, 1976 pp 141-142).

1.11.3 Limited conclusion

When the bite mark is composed of elements which lack specificity, conclusions are limited to identifying the mark as a bite mark without reference to an individual.

1.12 AIMS

The research initially consisted of a review of bite mark cases which is reported in Chapter 2. The aims of the retrospective study were to confirm the relevance of the selected anatomical site and to determine the validity of the criteria described by Rawson et al (1984a). A preliminary study of posture distortion in the female breast utilising two subjects is reported in Chapter 3. A more detailed study of posture distortion in the female breast in a larger number of subjects is reported in Chapters 4-8.

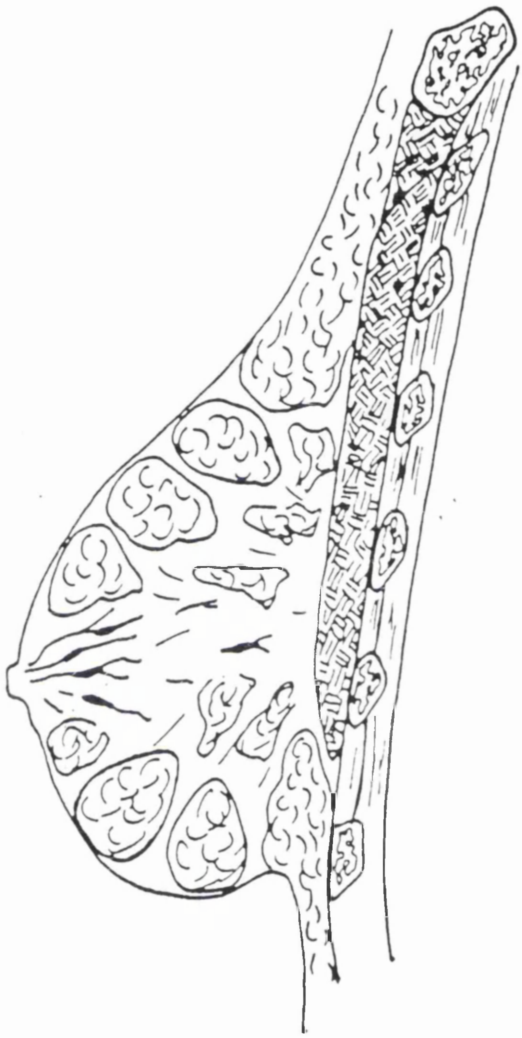


Figure 1.1 Attachment of the breast from the second to the sixth rib and from the sternum to the outer axillary line (Modified from Netter, 1977)

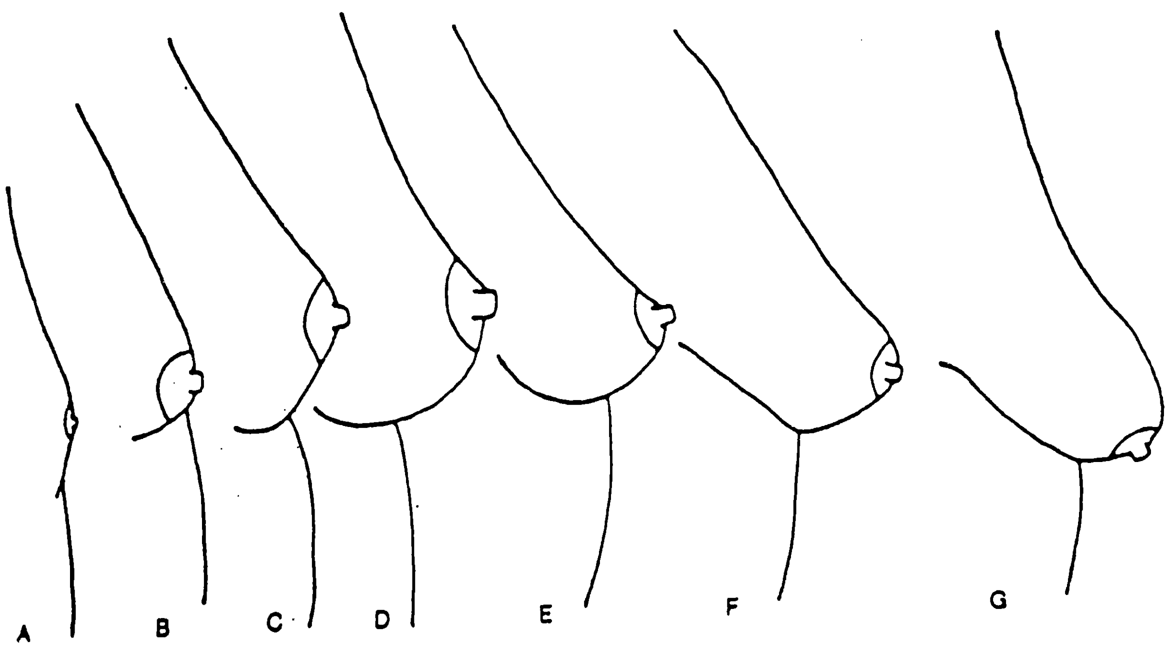


Figure 1.2
Diagrammatic classification of the female breast (after Rawson and Brooks, 1984)
A Adolescent, B Pubertal, C Adult developing, D Adult mature, E Adult, first-degree ptosis, F Adult, second-degree ptosis, G Adult, third-degree ptosis

ABFO SCORING SHEET FOR BITE MARK ANALYSIS

(Important: Use only with scoring guide, score only *reliable* information)

Case Name: ______________________________ SCORE

Features analyzed	No. of Points	Max	Mand	Discrepancy (if any)
GROSS 1. All teeth in mark present in suspect's mouth	•One per arch			
2. Size of arches consistent	•One per arch			
3. Shape of arches consistent	•One per arch			
TOOTH POSITION 4. Tooth and mouth mark in same labiolingual position	•One per tooth			
5. Tooth and mark in same rotational position (whether rotated or normal)	•One per tooth			
6. Vertical position of tooth re. occlusal plane matches depth of mark (use *only in unusual case*)	One per matching tooth			
7. Spacing between adjacent marking edges	•One per space			
INTRADENTAL FEATURES 8. Mesiodistal width of tooth matches mark *(use only if individual tooth is clearly marked)*	•One per tooth			
9. Labiolingual width of tooth matches mark OR attrition of edge matches mark	••Three per tooth			
10. Distinctive curvature of tooth incisal edge matches mark *(use only in unusual case)*	Three per tooth			
11. Other distinctive features (fractured teeth, unusual anatomy)	Three per tooth			
MISCELLANEOUS 12. Suspect has one edentulous arch and this is reflected in bite mark	Three			
•Three points if feature is significantly distinctive ••Only in case permitting accurate measurement	Total, each arch:			
	Grand total:			

Signature ______________________________ Date

2/20/84 Committee on Bite Mark Guideleines
Raymond Rawson Norman Sperber Gerard Vale, Chairman

Figure 1.3 Copy of the scoring sheet recommended by the American Board of Forensic Odontology

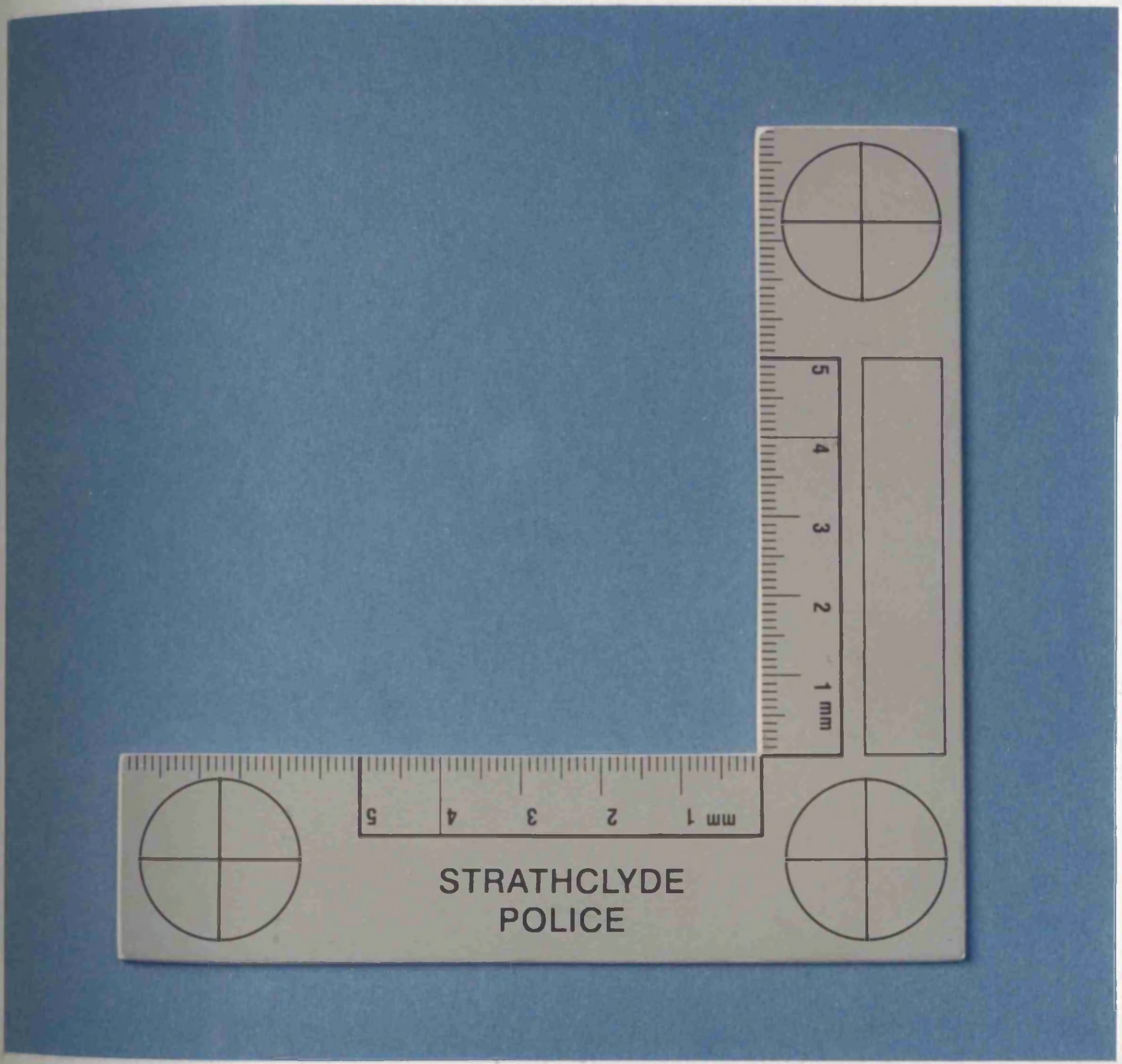


Figure 1.4 **A bite mark standard reference scale**

Chapter 2

BITE MARK CASE REVIEW

Chapter 2

BITE MARK CASE REVIEW

2.1 INTRODUCTION

Experimental research of human bite marks in human skin is, by its nature, difficult to conduct. Consequently, the initial research consisted of a review of bite mark cases investigated in Glasgow which occurred in Britain between 1971 and 1989. The bite marks occurred in the crimes of assault, rape, murder and child abuse. The review of the bite marks provided the opportunity to pose fundamental questions. The decision making processes involved in answering the questions produced an insight into the development of understanding and learning the science and art of bite mark analysis.

2.2 AIMS

The aims of the bite mark case review were twofold. The first aim of the retrospective study was to confirm the relevance of the female breast as the selected anatomical site for research. The second aim was to determine the validity, in bite mark cases, of the criteria described by Rawson et al (1984a).

2.3 MATERIALS AND METHODS

A total of 31 bite mark cases was included in the review. The photographic print utilised in the original bite mark analysis of each case was selected for the review. The 31 photographic prints demonstrated a marked variation in the quality of the bite marks. An example of a good, an average and a poor quality bite mark is illustrated in Figures 2.1a, 2.1b and 2.1c respectively. The retrospective study initially focused on the incidence of age, sex, multiple bite marks and anatomical location.

The review of the overall bite mark consisted of the recognition and interpretation of the following features - orientation of the mark, arch centre point, arch size and arch shape. This was achieved by posing the following respective questions - can the upper and lower arches be oriented in the mark ? Can the arch centre point be determined ? Can the arch size be determined ? Can the arch shape be determined ? The orientation of the upper and lower arches was possible because the upper arch was usually represented by the larger arc composed of larger individual tooth elements. The arch centre point and arch size were difficult to assess if the arch representation consisted of an incomplete arc. The upper and lower arch representation was usually almost circular or oval.

The individual tooth elements of the bite mark comprised the upper and lower central incisors, lateral incisors, canines and first premolars. The review of the individual tooth elements consisted of the recognition and interpretation of the following features - presence or absence, quality and position. The absence of an individual element may have been false. A non-injured space might indicate either an absent tooth or a deficiency in the incisal/cuspal level or the presence of clothing at the time of biting. The quality of the individual elements ranged from an indistinct to a detailed representation. The number of the individual elements varied from a few to the complete anterior dentition. Quality was scored 1 for good, 2 for average and 3 for poor. Position was denoted N for normal and A for abnormal. The review of the bite marks was repeated after an interval of two months in order to minimise any preconditioning influence.

2.4 RESULTS

2.4.1 Age and Sex

The incidence of the bite mark cases in adults and children is shown in Table 2.1. The review demonstrated that the relative incidence for adults and children was 87% and 13% respectively. The findings represented a marked variation in age incidence. The sex incidence in adult females and males was 63% and 37% respectively; the incidence in female children was 75% compared with 25% in male children.

2.4.2 Multiple marks

Of the 31 bite mark cases reviewed, 13 cases demonstrated multiple bite marks. Therefore, multiple bite marks occurred in 42% of the cases. There were a further five cases of adult females who demonstrated multiple marks which were allegedly bite marks. The bite mark analysis of these cases recorded only one mark which could be positively identified as a bite mark, the other marks could not be identified as bite marks. Consequently, the incidence of the multiple bite marks could potentially have been 58% of the cases.

2.4.3 Anatomical location

The anatomical locations of the bite marks in adults and children are shown in Table 2.2. The review demonstrated that the most commonly bitten location in females and males was the breast and face respectively.

2.4.4 Overall bite mark

The results of the reviews of the overall bite mark are shown in Table 2.3. The results for each bite mark demonstrated consistent responses to orientation of the mark and determination of arch centre point, arch size and arch shape, with only one exception in the first review. Positive orientation of the mark and determination of the arch centre point, size and shape was found in 58% and 61% of the bite marks in the two reviews respectively. Inability to orient the mark and to determine the arch centre point, size and shape was found in 42% and 39% of the bite marks in the two reviews respectively. Positive results were more frequent than negative results.

2.4.5 Individual tooth elements

The results of the reviews of the individual tooth elements are shown in Tables 2.4 and 2.5.

The incidence of the presence and absence of central incisors, lateral incisors, canines and first premolars were expressed in percentage terms as shown in Table 2.6. The incidence of the presence of individual elements demonstrated an incremental decline from approximately 67% for upper central incisors to approximately 40% for canines. The incidence of the presence of first premolars was low at approximately 7%. The incidence of the absence of individual elements demonstrated complementary values. Therefore, an incremental increase from approximately 33% for upper central incisors to approximately 60% for canines. The incidence of the absence of first premolars was high at approximately 93%. The upper central incisors demonstrated a higher incidence of presence than lower central incisors. Otherwise, lateral incisors, canines and first premolars demonstrated incidence values which were relatively uniform for each tooth type.

The incidence of the quality of central incisors, lateral incisors, canines and first premolars were expressed in percentage terms as shown in Table 2.7. With the exception of the first premolars, approximately 50% of the individual elements demonstrated poor quality. The remaining 50% consisted of a greater proportion of average quality elements, good quality elements formed the minority group. The first premolars demonstrated quality values higher than the other teeth There was relative consistency in the quality values for each tooth type.

The position of the individual elements was normal in almost all cases.

2.5 DISCUSSION

The higher incidence values for adult females and the high incidence of multiple bite marks were considered to be significant findings. The review findings of multiple bite mark incidence and that the most commonly bitten anatomical location in females was the breast compared favourably with Vale and Noguchi (1983). However, the male finding that the face was the most commonly bitten location was at variance with Vale and Noguchi, who stated that the arms and shoulders were the most commonly bitten anatomical locations.

Rawson et al (1984a) stated that, if the correlation was high between the bite mark and the dentition, there could be an assurance that no other dentition could have caused the mark as long as the individual tooth marks were within ± 1 mm of centre point and ± 5° angle variation of each individual tooth. Clearly, the validity of Rawson's criteria only applies to a good quality bite mark which represents the incisal edge/cupsal anatomy accuracy and completely. As the quality of the bite mark diminishes, the validity of Rawson's criteria correspondingly diminishes. This was reflected in the retrospective study which consisted of bite mark cases which demonstrated a range in the quality of the bite marks; good quality individual tooth elements formed the minority group. Indeed, Rawson referred to "testing the observational limits" and "developing a better understanding of distortion" in bite mark cases.

The reviews of the overall bite marks and the individual tooth elements were conducted by posing fundamental questions. The answers to the questions involved varying degrees of subjective judgment which was reflected in the findings of the two reviews. The questions posed of the overall bite marks, the presence or absence and the position of the individual elements were relatively simple and consequently required minimal subjective judgment which was reflected in minor differences in the two reviews. The questions posed of the quality of the individual tooth elements were more complex and therefore required increased subjective judgment which was reflected in greater differences in the two reviews. The results of the two reviews demonstrated that the questions posed determined the degree of subjective judgment involved in the answer.

Furthermore, the standard of subjective judgment depends on the ability and the experience of the forensic dentist. The reviews were conducted by an inexperienced examiner whose answers to the relatively simple questions of the overall mark, the presence or absence and the position of the individual elements were relatively consistent between the two reviews. However, the more complex question of the quality of the individual elements produced answers which varied between the two reviews. The influence of the experience of the examiner could be assessed by comparing the results of experienced and inexperienced examiners.

Bite mark analysis is conducted initially by posing the same fundamental questions. The reviews highlighted the variation in subjective judgment utilised in bite mark analysis. The practical application is twofold. Firstly, the forensic dentist should conduct analysis on a repeat basis with an adequate time interval between each analysis. Secondly, two forensic dentists should report independently on each case.

2.6 CONCLUSIONS

Bite marks were found mainly in adults and occurred more often in females than males. The most commonly bitten anatomical location in females was the breast and in males the face. These conclusions confirmed the relevance of the female breast as the selected anatomical site for research. The incidence of single bite marks and multiple bite marks was comparable.

The presence of the individual tooth elements demonstrated incremental variations between the four tooth types; central incisors were represented most frequently and first premolars least frequently. The position of the individual tooth elements was normal. The quality of the individual tooth elements was variable, good quality elements formed the minority group. In bite mark cases, the validity of the criteria described by Rawson et al (1984a) was limited to good quality bite marks, the minority group in this review.

Subjective judgment was an important variable factor in bite mark analysis and was dependent on the questions posed and the ability and experience of the forensic dentist.

Figure 2.1a An example of a good quality bite mark

Figure 2.1b An example of an average quality bite mark

Figure 2.1c An example of a poor quality bite mark

	ADULT		CHILD	
	Female	**Male**	**Female**	**Male**
Number of cases	17	10	3	1
Number of cases demonstrating multiple bite marks	6	5	1	1
Number of cases demonstrating multiple marks	11	5	1	1

Table 2.1 Incidence of the bite mark cases in adults and children

	ADULT		CHILD	
	Female	**Male**	**Female**	**Male**
Face	1	5	2	
Neck	3			
Back	1	1		
Chest (males)		1		1
Breast (females)	5			
Abdomen	2	1		
Buttock	1			
Arm	3	2	1	
Hand	1			

Table 2.2 The anatomical locations of the bite marks in adults and children

Bite Mark	Orientation of Mark	Arch Size	Arch Shape	Arch Centre Point
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes
4	No	No	No	No
5	Yes	Yes	Yes	Yes
6	No	No	No	No
7	Yes	Yes	Yes	Yes
8	No	No	No	No
9	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes
11	No	No	No	No
12	Yes	Yes	Yes	Yes
13	Yes	Yes	Yes	Yes
14	No	Yes (No)	Yes (No)	Yes (No)
15	Yes	Yes	Yes	Yes
16	No	No	No	No
17	No	No	No	No
18	No (Yes)	No (Yes)	No (Yes)	No (Yes)
19	No (Yes)	No (Yes)	No (Yes)	No (Yes)
20	Yes	Yes	Yes	Yes
21	No	No	No	No
22	Yes	Yes	Yes	Yes
23	Yes	Yes	Yes	Yes
24	No	No	No	No
25	No	No	No	No
26	Yes	Yes	Yes	Yes
27	No	No	No	No
28	No	No	No	No
29	Yes	Yes	Yes	Yes
30	Yes	Yes	Yes	Yes
31	Yes	Yes	Yes	Yes

Table 2.3 **Reviews of the overall bite mark** (when the second review differed from the first, the second review data are shown in brackets)

Tooth	Present	Absent	Quality			Position	
			1	2	3	N	A
11	21	10	3	7	11	19	2
21	22	9	4	5	13	21	1
41	18	13	2	8	8	18	0
31	17	14	3	6	8	17	0
12	16	15	2	4	10	15	1
22	16	15	2	5	9	16	0
42	15	16	2	6	7	14	1
32	14	17	2	5	7	14	0
13	13	18	2	5	6	13	0
23	12	19	3	4	5	12	0
43	13	18	2	6	5	13	0
33	13	18	2	5	6	13	0
14	2	29	2	0	0	2	0
24	2	29	1	1	0	2	0
44	2	29	2	0	0	2	0
34	2	29	2	0	0	2	0

Table 2.4 First review of the individual tooth elements

Tooth	Present	Absent	Quality			Position	
			1	2	3	N	A
11	20	11	2	8	10	19	1
21	20	11	2	7	11	20	0
41	17	14	1	8	8	17	0
31	16	15	1	8	7	16	0
12	17	14	2	5	10	16	1
22	13	18	2	3	8	13	0
42	14	17	1	4	9	13	1
32	14	17	1	5	8	14	0
13	13	18	1	5	7	13	0
23	11	20	1	6	4	11	0
43	11	20	1	3	7	11	0
33	12	19	1	4	7	11	1
14	3	28	0	2	1	3	0
24	3	28	0	2	1	3	0
44	2	29	0	2	0	2	0
34	2	29	0	2	0	2	0

Table 2.5 Second review of the individual tooth elements

TEETH	PRESENT		ABSENT	
	First Review	Second Review	First Review	Second Review
11 21	69	65	31	35
41 31	56	53	44	47
12 22	52	48	48	52
42 32	47	45	53	55
13 23	40	39	60	61
43 33	42	37	58	63
14 24	6	10	94	90
44 34	6	6	94	94

Table 2.6 **Percentage incidence of the presence and absence of individual tooth elements**

TEETH	QUALITY					
	good		average		poor	
	First Review	Second Review	First Review	Second Review	First Review	Second Review
11 21	16	10	28	37	56	53
41 31	14	6	40	48	46	46
12 22	13	13	28	27	59	60
42 32	14	7	38	32	48	61
13 23	20	8	36	46	44	46
43 33	16	9	42	30	42	61
14 24	75	0	25	67	0	33
44 34	100	0	0	100	0	0

Table 2.7 Percentage incidence of the quality of individual tooth elements

Chapter 3

POSTURE DISTORTION - PRELIMINARY STUDY

Chapter 3

POSTURE DISTORTION - PRELIMINARY STUDY

3.1 INTRODUCTION

In 1990 a series of bite marks and other injuries were inflicted on a female in a case of rape in Liverpool. The police photographer recorded the injuries without dental supervision. The body position at the time of biting was not recorded. One of the bite marks was inflicted on the outer surface of the right breast and the photographs recording this mark were taken with the victim's right arm in two different positions on successive days. The appearance of the bite mark varied markedly between the photographs taken on the two days. The bite mark with victim's arm raised to an unknown position on the first day and by her side on the second day are illustrated in Figures 3.1 and 3.2 respectively. The dimensions of the bite mark varied substantially between the photographic prints. The overall bite mark measured 40mm horizontally and 50mm vertically in Figure 3.1 and 45mm horizontally and 40mm vertically in Figure 3.2 The measurements represented a 12.5% variation in the horizontal plane and a 25% variation in the vertical plane. The bite mark underwent distortion horizontally and vertically as the victim's arm was raised from her side. The variation in the measurements between the photographic prints of the same bite mark was posture distortion produced by arm movement.

The Liverpool case provided an example of posture distortion in the female breast in a bite mark case. The occurrence of posture distortion percentage values of the order of 25% was considered to be of major importance to bite mark analysis. Furthermore, in female victims, bite marks are most common on the breasts (Vale and Noguchi, 1983). These observations provided the stimulus for research into posture distortion in bite marks in the female breast.

3.2 AIMS

The preliminary study of posture distortion in the female breast reported in this Chapter utilised the technique of creating study marks on different breast sites. The posture distortion produced by arm movement was recorded by photography.

The aims of the preliminary study were to research posture distortion in the female breast utilising two subjects. Specifically, the objectives were to quantify posture distortion in the female breast, to compare posture distortion in different breast sites and to study the influence of arm movement on posture distortion

3.3 MATERIALS AND METHODS

3.3.1 Creation of study marks

It was clearly inappropriate to attempt to inflict multiple bite marks on the breasts of volunteers. The technique of noting distortion of a mark on skin made with a rubber stamp was illustrated by Harvey (1976) and it was thought that development of that technique could provide appropriate study marks.

Study marks were created by a specially prepared die stamp constructed by the Department of Prosthodontics, Glasgow Dental Hospital and School (Figure 3.3) The die stamp surface was designed to reflect the dimensions encountered in bite mark cases (Moorress, 1959; Rawson et al, 1984a). The design allowed measurements to be recorded horizontally, vertically and diagonally. The die stamp consisted of a cobalt chrome casting measuring 34mm square with edges 1mm wide. A circle with edges 1mm wide was located within the square. Notches 1mm wide were located on the mid-point of the casting edges and coincident with the diagonals on the inner circle edge. In addition to providing measurement points, it was felt that the 1mm wide notches might simulate gaps between teeth. One edge was designated the "top" and marked accordingly in order to maintain consistency when orienting the die stamp. The surface of the die stamp was flat.

In order to record study marks, the die stamp surface was pressed against a Swallow brand black ink pad. The inked surface of the die stamp, with the "top" edge uppermost, was applied to the breast surface with the minimum pressure required to ensure a complete and accurate reproduction of the die stamp surface. The study marks were readily removed using a damp cloth following which the surface was dried with a towel, prior to any further study marks being made.

The study marks were created on four sites on each breast - the outer surface, the upper surface, the inner surface and the nipple. The lower surface was not included; this site is infrequently bitten and the practicalities of studying distortion in the lower site were considered too great. In order to obtain consistency in mark location, the study marks on the outer, upper and inner sites were located with one edge of the die stamp immediately adjacent to the areola (Figure 3.4a). The study mark on the nipple site was located centrally on the areola over the nipple (Figure 3.4b).

3.3.2 Subjects

The preliminary study of posture distortion in the female breast was undertaken using two subjects. Photographs were taken of frontal and lateral views of each subject and of study mark views of the four sites on each breast. The subjects were photographed by Professor D G MacDonald, accompanied as required by a female chaperon, in the Department of Oral Sciences, Glasgow Dental Hospital and School.

3.3.3 Photographic equipment

The camera of choice was an Olympus OM10 which is a single lens reflex camera fitted with an 80mm lens and a 20mm extension ring. Initially, various methods of camera support were considered. The photographic tripod was inappropriate because it lacked the range of camera positions required to photograph the variations in breast surface angulation. The photographic monopod enabled the camera position to be varied widely which largely overcame this problem. However, it was found that certain views, for example, the upper surface of the breast, were outwith the monopod's range. Consequently, it was concluded that a hand-held camera would be the best method of photographing the complete range of study marks on the breast.

The flash unit used to record the frontal and lateral views of each subject was a Panasonic PE-145 hot shoe fitting. The study mark views of each breast site were recorded with a Starblitz 1000 -Auto Macro-Lite ring flash unit.

The photographic film was Kodak Panatomic - X32 which is a 35mm film for black and white prints. The photographs were printed on Ilfabrom printing paper.

3.3.4 Scales

It was necessary to develop a system which would produce accurately scaled photographic prints. Initial development commenced with a prototype arm which consisted of a metre plastic ruler with two Rabone rulers at right angles fixed to the end of the ruler. Trial photographs of study marks were taken in order to demonstrate the scale on two adjacent margins of the print. The objective was to be able to record marks with maximum posture distortion in the lens field with the scale on two adjacent margins. The camera to scale distance which fulfilled this objective was 47cm. Trials with the initial measurement frame demonstrated that it was not sufficiently rigid.

The further development of the extension arm with measurement frame was designed to ensure parallelism between the film and the mark, coupled with a scale on the margins of each photographic print. The extension arm with measurement frame consisted of a rigid aluminium arm and a stainless steel frame as shown diagrammatically in Figure 3.5. The frame incorporated four Rabone Chesterman No. 64R rulers. These are machined rigid metal rulers conforming to Imperial Standards. The plane of the rulers was parallel to the film plane at a fixed distance of 47cm. The rulers were bonded to the measurement frame to create an aperture measuring 90mm x 60mm in order to provide a scale round the entire margin of the field of the 35mm film . The measurement frame aperture mid-point was coincident with the assembly centre line; the angles of the measurement frame aperture were all right angles. The plane of the rulers was at right angles to the assembly centre line. The extension arm was secured to the camera base by a stainless steel fixing screw. This permitted minimal lateral camera adjustment to locate the mark adjacent to the rulers' scales in the measurement frame. The measurement frame was painted black to eliminate reflected flash glare which compromised the appearance of the rulers. The extension arm with measurement frame was constructed by the Department of Clinical Physics and Bio-Engineering, Greater Glasgow Health Board.

3.3.5 Photography of study marks

In order to facilitate an understanding of the overall posture distortion in the breast produced by arm movements, an initial sequence of photographs was taken consisting of three frontal views and one lateral view of each subject. The frontal views, taken with the subject standing, were from the neck to the waist with the arms extended in three different positions in the same plane, namely the subject's side. The three positions, arms vertically down, arms horizontal and arms vertically up, were photographed as illustrated in Figure 4.1. The lateral view, taken with the subject standing, were from the neck to the waist with the arms vertically down by the side as illustrated in Figure 4.2. The camera with Panasonic flash unit was supported by a monopod at a film to subject distance of approximately 1.5 metres; the camera setting was manual $^{1}/_{30}$ second at F11.

The study mark views of the four sites on each breast were photographed using the camera with Starblitz ring flash unit, attached to the extension arm with measurement frame (Figure 3.6). The assembled photographic equipment was hand-held during the photographic sequence while the subject remained standing; the camera setting was manual $^{1}/_{30}$ second at F8.

By design and construction the plane of the rulers was parallel to the film plane at a fixed distance of 47cm. Care was taken to ensure that the plane of the rulers and the plane of the study mark were as coincident as possible resulting in near parallelism between the mark and the film. The breast surface with the study mark was located in the lower left quadrant of the measurement frame to provide two scales close to adjacent margins of the mark.

A study mark was created on each site with the adjacent arm extended in each of the three different positions in the same plane, namely the subject's side. The three positions recorded were, the arm vertically down, the arm horizontal and the arm vertically up. The other arm remained by the subject's side. Each study mark was photographed initially with the arm in the same position as the mark had been recorded as illustrated in Figure 3.7a. The remaining two photographs were taken with the arm in the other two positions as illustrated in Figures 3.7b and 3.7c. This sequence produced nine photographs for each of the four sites and consequently 36 photographs for each breast. The complete photographic sequence of the left and right breasts is demonstrated in Tables 3.1 and 3.2 respectively. The resultant photographic file for each subject therefore consisted of 72 prints. Film development and printing were conducted using standard manual techniques. The prints were enlarged times two in order to facilitate measurement.

3.3.6 Measuring of photographic prints

The measurements were recorded by the author from each of the photographic prints. The points selected for measurement are shown diagrammatically in Figure 3.8. Using direct vision, a Rabone ruler was placed with the 10mm mark on one point and the other point was recorded by deducting 10mm from the reading. This technique ensured that both points were aligned along the ruler edge thereby standardising the recording of measurements. The measurements were recorded to the nearest millimetre. The photographic prints were enlarged times two and consequently the measurement values were twice the actual sizes. The sequence of measurements of the left and right breasts is demonstrated in Tables 3.3 and 3.4 respectively. The measurement sequence produced 16 measurements for each print. The measurement sequence was repeated for each print.

3.3.7 Data collection

The photographic file for each subject consisted of 72 prints. The measurement sequence produced 16 measurements for each print which resulted in 1,152 measurement values for each subject and 2,304 measurement values in total for the preliminary study.

The photographic sequence produced nine prints for each of the four sites. The measurement values for each of the four breast sites were recorded as shown in Table 3.5. Consequently, the data consisted of eight tables for each subject; a total of 16 tables for the preliminary study.

3.3.8 Creation of measurement tables

The measurement values were transferred manually onto a personal computer and the software package Minitab was used for the creation and analysis of measurement tables.

In order to allow comparisons to be made between sites and between subjects it was felt that the most useful data would be assessments of the distortion found between the three photographic prints of individual study marks. In other words, the percentage change in individual values was assessed between the mark photographed with the arm positioned when the mark was made and the arm moved to the further two positions.

The sequence of creation of the data for analysis is demonstrated in Table 3.6 with respect to the study mark illustrated in Figures 3.7a, b and c. The assessment of posture distortion was by subtraction of the values of individual measurements obtained in the positions with the arm moved from the corresponding values in the photographs taken with the arm in the position in which the mark was made. If the measurement was increased with arm movement, this gave a negative value for the tabulated distortion. Conversely, if the measurement was decreased with arm movement, this gave a positive value. This value was converted to a percentage difference with respect to the value in the first photograph. As a convention for this thesis, the signs were left unchanged and therefore a positive value in the measurement tables reflects a contraction for posture distortion and a negative value reflects an expansion.

The complete tabulation of posture distortion percentage values was then derived for each breast, involving four sites per breast and sequences of distortion between three study marks per site. In order to simplify the presentation of the data, the order of the rows in the measurement table was adjusted to display together vertical values, horizontal values and diagonal values. The designation of the rows in the measurement tables in this Chapter is shown in Table 3.7

3.3.9 Analysis of measurement tables

The posture distortion percentage values of the measurement tables comprised positive, negative and zero values which related to contraction, expansion and no distortion respectively. The analysis of the measurement tables commenced by studying the range of contraction and expansion values and the frequency of no distortion. The posture distortion percentage values of the left and right breasts were compared for each subject. The analysis therefore quantified posture distortion in the female breast, compared posture distortion in the four sites on each breast and studied the influence of arm movement on posture distortion.

3.4 RESULTS

Subject 1 was aged 50 with a bust size of 32 inches and cup size A. Subject 2, aged 42, had a bust size of 36 inches and cup size A. The initial frontal photographs demonstrated dimensional changes in breast morphology produced by the different arm positions as illustrated in Figure 4.1. The degree of dimensional change was related to the extent of arm movement. The changes in breast morphology demonstrated minor differences between the left and the right breasts of each subject.

In order to demonstrate the range of contraction and expansion for each subject, the data are shown in duplicate tables. The range of posture distortion percentage values was colour coded as defined in Table 3.8. The contraction and expansion values for subject 1 are shown in Tables 3.9 and 3.10 respectively. The contraction and expansion values for subject 2 are shown in Tables 3.11 and 3.12 respectively. The posture distortion percentage values demonstrated a range from 26.09% contraction to 37.78% expansion. The expansion values were greater than the contraction values. The contraction values were highest in the outer site for the two subjects. The expansion values were highest in the outer, inner and nipple sites for subject 1 and in the outer, upper and nipple sites for subject 2. The posture distortion values were generally lowest in the inner site for the two subjects. The most extensive arm movements produced the maximum posture distortion values.

The contraction and expansion values demonstrated patterns of distortion. The pattern of contraction values was comparable in the four sites on each breast of the two subjects. Arm movements in an upward direction produced contraction of the horizontal measurements and the upper medial to lower lateral diagonal measurements. Arm movements in an upward direction produced expansion of the vertical measurements and the upper lateral to lower medial diagonal measurements. Arm movements in a downward direction produced contraction of the vertical measurements and the upper lateral to lower medial diagonal measurements. Arm movements in a downward direction produced expansion of the horizontal measurements and the upper medial to lower lateral diagonal measurements. The pattern of expansion values was comparable in the four sites on each breast of the two subjects.

The frequency of contraction, expansion and no distortion in the four sites on each breast of the two subjects were expressed in percentage terms as shown in Table 3.13.

The results demonstrated that expansion was more frequent than contraction and the occurrence of no distortion was noteworthy.

The contraction values of the left and right breasts were comparable in each of the four breast sites of subject 1. The expansion values of the left and right breasts were comparable in each of the four breast sites of subject 1. The contraction values of the left and right breasts were comparable in each of the four breast sites of subject 2. The expansion values of the left and right breasts were comparable in the outer, upper and inner sites of subject 2; the nipple site demonstrated several values which were not comparable between the left and right breasts.

3.5 DISCUSSION

The preliminary study utilised three practical stages - creation of study marks, photography of study marks and measuring of photographic prints. The practical stages were designed to achieve as high a degree of standardisation and consistency as possible. This was necessary since the data produced would be analysed in a comparative way. Notwithstanding the attempts to achieve high levels of standardisation and consistency for comparative purposes, there existed an unavoidable subjective component which manifest itself differently in the three practical stages. During the creation of the study marks, tissue deformation was variable when the inked die stamp was applied to the breast surface. During the photography of the study marks, the hand-held camera with measurement frame produced minor variations in film to mark distance and film to mark parallelism. When measuring the photographic prints, it was observed that some points on the prints were less distinct and required a subjective decision; in addition, all measurements were recorded to the nearest millimetre. Prior recognition of the subjective elements resulted in great care and attention being taken to minimise their effect. As a consequence, the subjective component was minimal and was not considered to be a relevant factor in the preliminary study.

3.6 CONCLUSIONS

In each subject the posture distortion of the left and right breasts was comparable in the outer, upper and inner sites and was more variable in the nipple site. The magnitude of posture distortion was very variable. Maximum contraction occurred in the outer site. The site at which maximum expansion occurred varied. Minimum posture distortion occurred consistently in the inner site. Maximum posture distortion was produced by the most extensive arm movements. The posture distortion produced by arm movement exhibited complementary patterns of contraction and expansion in the four sites on each breast. The posture distortion percentage values of the preliminary study compared favourably with the posture distortion percentage values in the Liverpool case. Therefore, the preliminary study had succeeded in demonstrating posture distortion comparable to that in a bite mark case.

Figure 3.1 **The bite mark with the victim's arm raised to an unknown position**

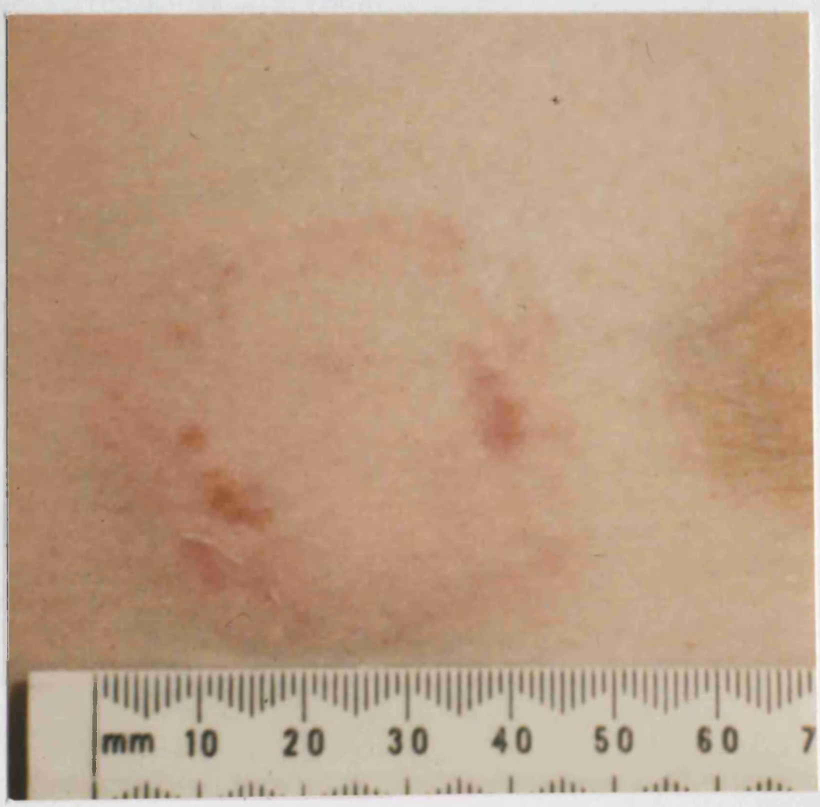


Figure 3.2 **The bite mark with the victim's arm by her side**

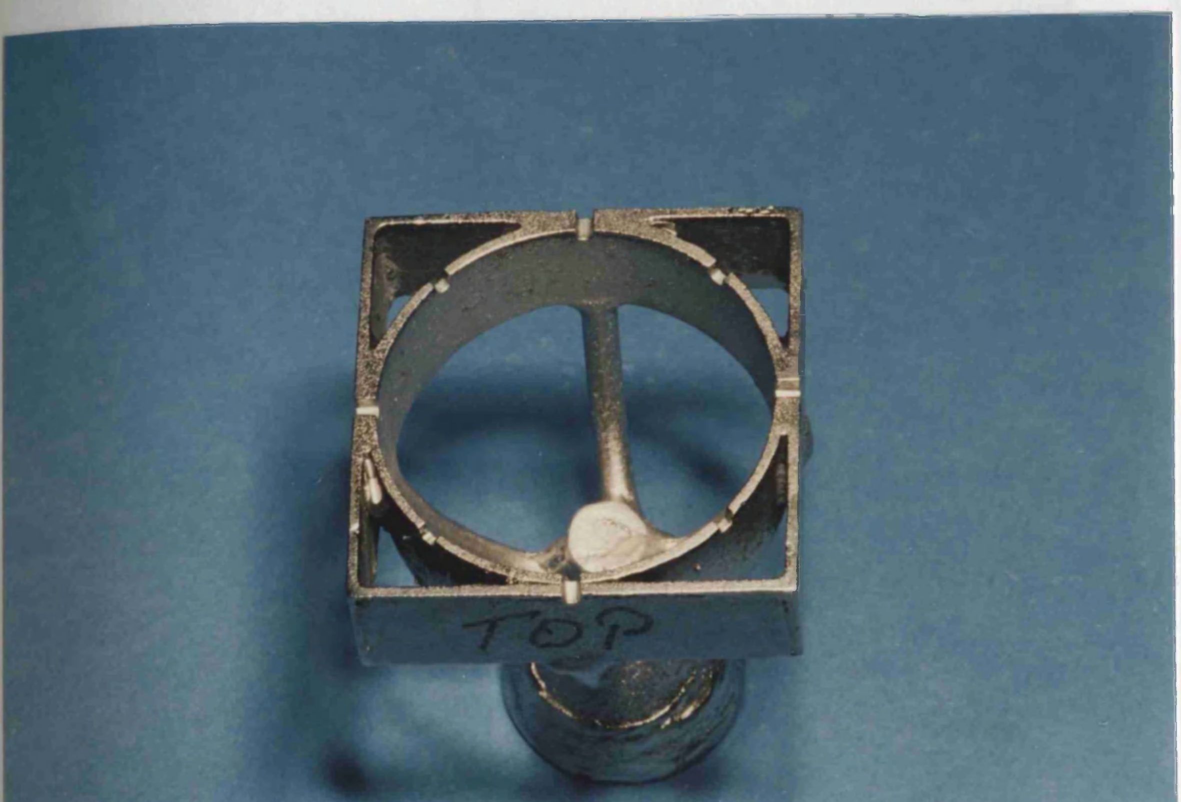


Figure 3.3 The die stamp

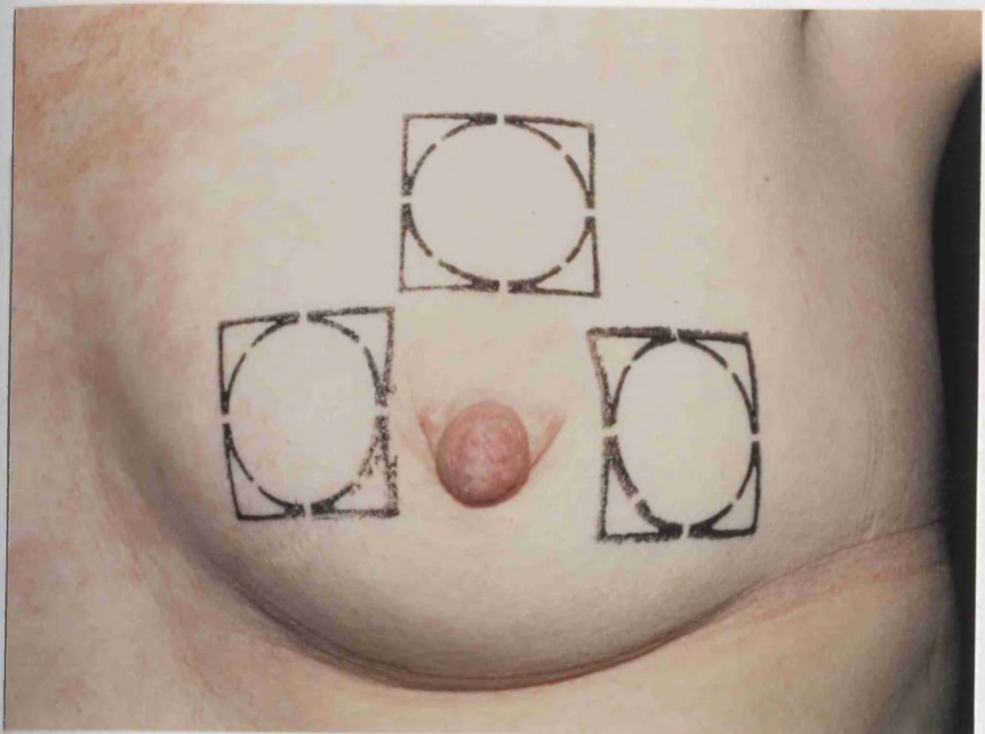


Figure 3.4a The outer, upper and inner sites

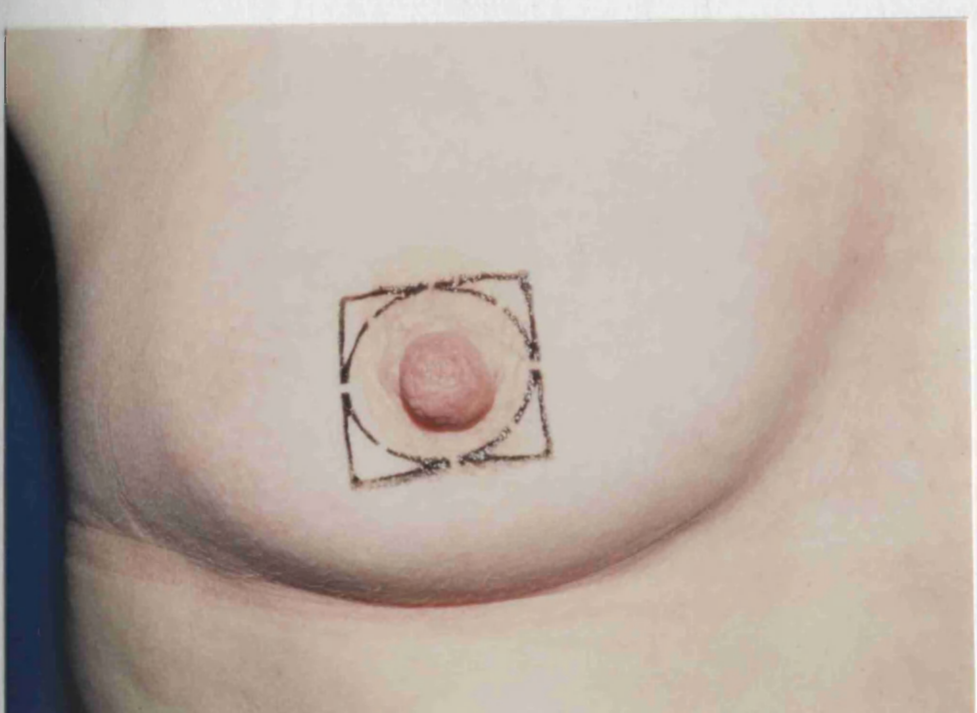


Figure 3.4b The nipple site

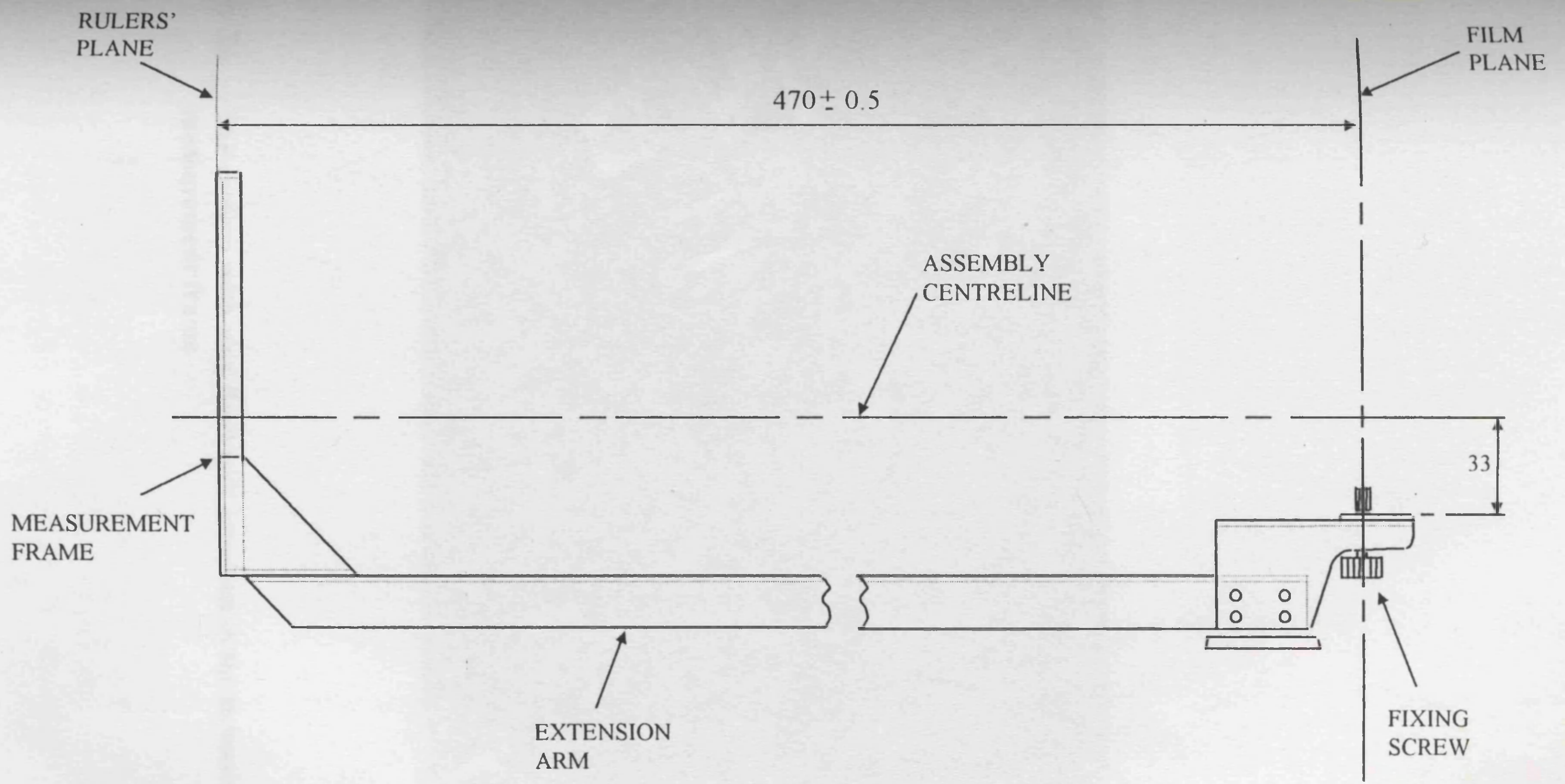


Figure 3.5 **Diagram of the extension arm with measurement frame**

Figure 3.6 The camera with ring flash unit attached to the extension arm with measurement frame

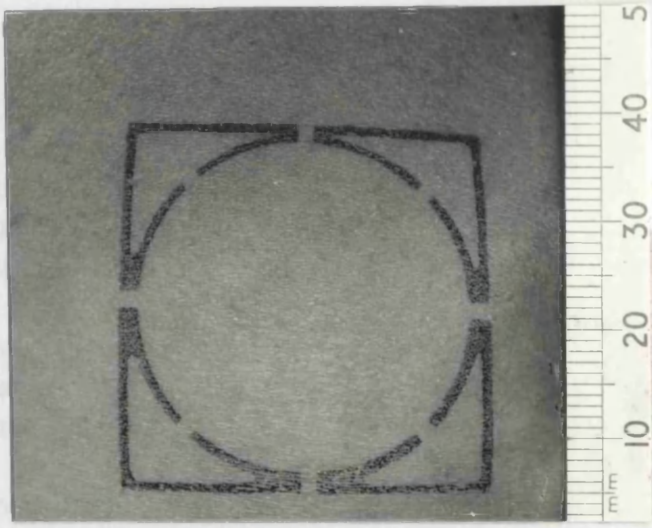


Figure 3.7a The study mark photographed with the arm in the same position as the mark had been recorded - down in this print

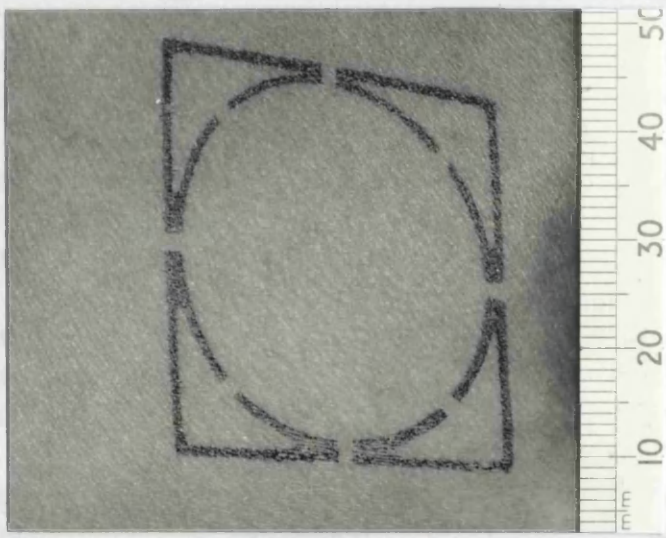


Figure 3.7b The same study mark photographed with the arm horizontal

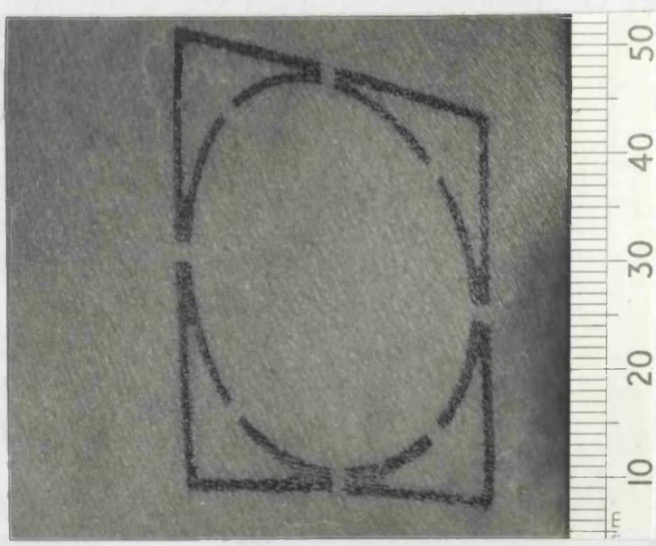


Figure 3.7c The same study mark photographed with the arm up

	Site	Mark Made (arm)	Photo (arm)
1	outer	down	down
	outer	down	horizontal
	outer	down	up
2	outer	horizontal	horizontal
	outer	horizontal	up
	outer	horizontal	down
3	outer	up	up
	outer	up	down
	outer	up	horizontal
4	upper	down	down
	upper	down	horizontal
	upper	down	up
5	upper	horizontal	horizontal
	upper	horizontal	up
	upper	horizontal	down
6	upper	up	up
	upper	up	down
	upper	up	horizontal
7	inner	down	down
	inner	down	horizontal
	inner	down	up
8	inner	horizontal	horizontal
	inner	horizontal	up
	inner	horizontal	down
9	inner	up	up
	inner	up	down
	inner	up	horizontal
10	nipple	down	down
	nipple	down	horizontal
	nipple	down	up
11	nipple	horizontal	horizontal
	nipple	horizontal	up
	nipple	horizontal	down
12	nipple	up	up
	nipple	up	down
	nipple	up	horizontal

Table 3.1 The photographic sequence of the left breast

	Site	Mark Made (arm)	Photo (arm)
13	outer	down	down
	outer	down	horizontal
	outer	down	up
14	outer	horizontal	horizontal
	outer	horizontal	up
	outer	horizontal	down
15	outer	up	up
	outer	up	down
	outer	up	horizontal
16	upper	down	down
	upper	down	horizontal
	upper	down	up
17	upper	horizontal	horizontal
	upper	horizontal	up
	upper	horizontal	down
18	upper	up	up
	upper	up	down
	upper	up	horizontal
19	inner	down	down
	inner	down	horizontal
	inner	down	up
20	inner	horizontal	horizontal
	inner	horizontal	up
	inner	horizontal	down
21	inner	up	up
	inner	up	down
	inner	up	horizontal
22	nipple	down	down
	nipple	down	horizontal
	nipple	down	up
23	nipple	horizontal	horizontal
	nipple	horizontal	up
	nipple	horizontal	down
24	nipple	up	up
	nipple	up	down
	nipple	up	horizontal

Table 3.2 The photographic sequence of the right breast

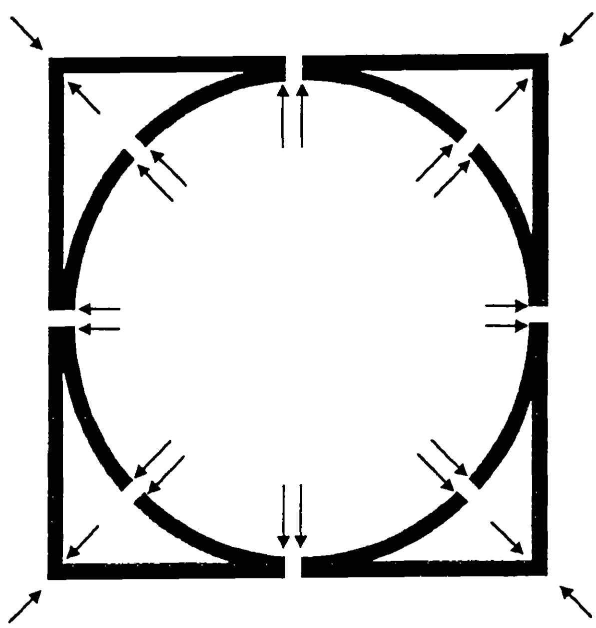
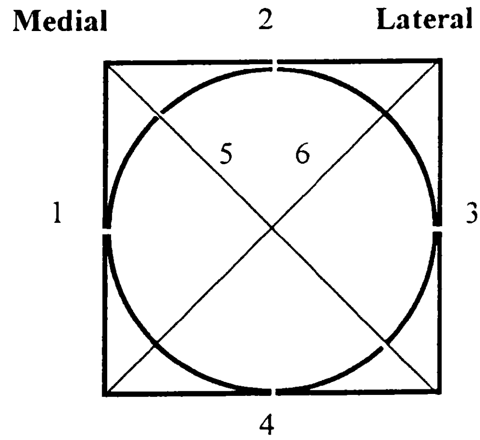
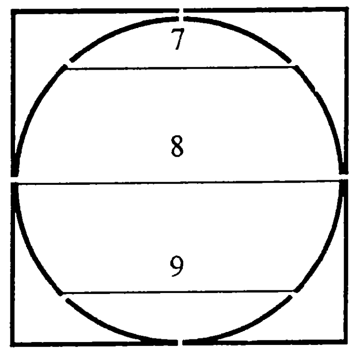


Figure 3. 8 Diagram of the measurement points used in the preliminary study

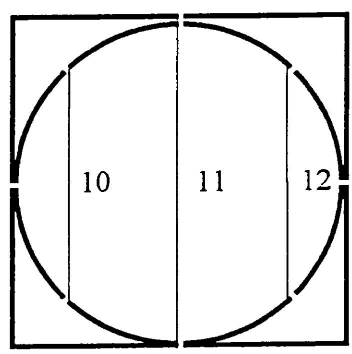
1. Medial edge
2. Upper edge
3. Lateral edge
4. Lower edge
5. Diagonal upper medial - lower lateral
6. Diagonal upper lateral - lower medial



7. Horizontal upper intercanine
8. Horizontal mid-point
9. Horizontal lower intercanine



10. Vertical medial intercanine
11. Vertical mid-point
12. Vertical lateral intercanine



13. Diagonal medial - upper
14. Diagonal upper - lateral
15. Diagonal lateral - lower
16. Diagonal lower - medial

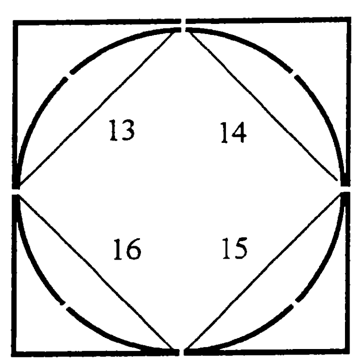
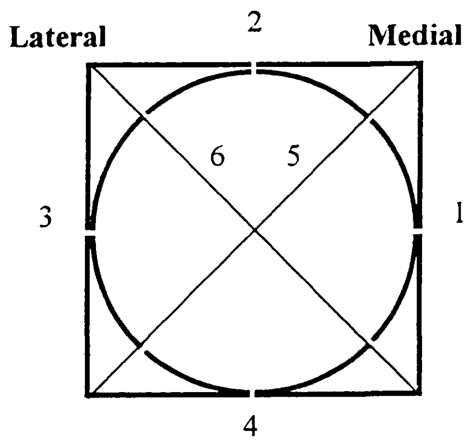
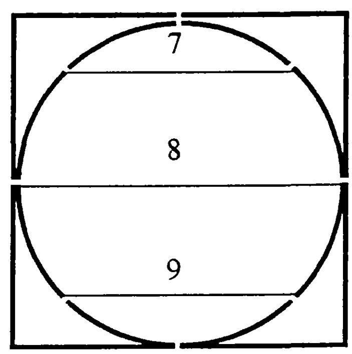


Table 3.3 The measurement sequence of the left breast

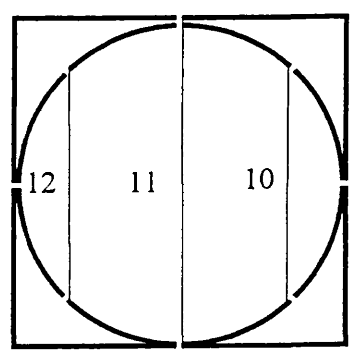
1. Medial edge
2. Upper edge
3. Lateral edge
4. Lower edge
5. Diagonal upper medial - lower lateral
6. Diagonal upper lateral - lower medial



7. Horizontal upper intercanine
8. Horizontal mid-point
9. Horizontal lower intercanine



10. Vertical medial intercanine
11. Vertical mid-point
12. Vertical lateral intercanine



13. Diagonal medial - upper
14. Diagonal upper - lateral
15. Diagonal lateral - lower
16. Diagonal lower - medial

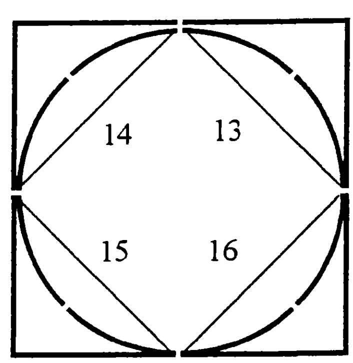


Table 3.4 The measurement sequence of the right breast

Subject - **Site -**

Mark made	Arm Down			Arm Horizontal			Arm Up		
Photo arm	Down	Horiz	Up	Down	Horiz	Up	Down	Horiz	Up
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									

Table 3.5 The measurement record of the nine photographic prints of a single breast site in each of the three arm positions

Element of study mark	Photographic print measurement			Posture distortion percentage value	
	DD	DH	DU	DD-DH	DD-DU
Medial edge	67	69	73	-2.99	-8.96
Upper edge	65	62	60	4.62	7.69
Lateral edge	68	78	87	-14.71	-27.94
Lower edge	68	62	56	8.82	17.65
Diagonal upper medial - lower lateral	88	83	84	5.68	4.55
Diagonal upper lateral - lower medial	91	98	102	-7.69	-12.09
Horizontal upper intercanine	45	43	41	4.44	8.89
Horizontal mid-point	62	57	53	8.06	14.52
Horizontal lower intercanine	46	42	38	8.70	17.39
Vertical medial intercanine	46	48	51	-4.35	-10.87
Vertical mid-point	62	66	71	-6.45	-14.52
Vertical lateral intercanine	48	53	58	-10.42	-20.83
Diagonal medial-upper	42	46	48	-9.52	-14.29
Diagonal upper-lateral	40	38	38	5.00	5.00
Diagonal lateral-lower	43	45	47	-4.65	-9.30
Diagonal lower-medial	40	37	36	7.50	10.00

Table 3.6 Creation of the data for analysis derived from the three photographic prints of subject 1 for the outer surface of the right breast. The mark was made with the arm down (D) and photographed in the three arm positions - down (D), horizontal (H) and up (U). The abbreviations used for these positions were therefore DD, DH and DU.

Row	Element of study mark
1	Medial edge
2	Vertical medial intercanine
3	Vertical mid-point
4	Vertical lateral intercanine
5	Lateral edge
6	Upper edge
7	Horizontal upper intercanine
8	Horizontal mid-point
9	Horizontal lower intercanine
10	Lower edge
11	Diagonal upper-lateral
12	Diagonal upper medial-lower lateral
13	Diagonal lower-medial
14	Diagonal medial-upper
15	Diagonal upper lateral-lower medial
16	Diagonal lateral-lower

Table 3.7 Designation of the rows in the measurement tables

0.0			blue
0.1	-	10 inclusive	green
10.1	-	20 inclusive	magenta
20.1	-	30 inclusive	*red*
30.1	-	40 inclusive	[illegible]

Table 3.8 Colour coding of the magnitude of posture distortion percentage values demonstrated in Tables 3.9 - 3.12

		Outer		Upper		Inner		Nipple		Outer		Upper	
		DD-DH	DD-DU	DD-DH	DD-DU	DD-DH	DD-DU	DD-DH	DD-DU	HH-HD	HH-HU	HH-HD	HH-HU
	Left												
	1	-2.99	-5.97	-2.90	-7.25	-2.86	-7.14	-4.35	-8.70	0.00	-8.70	5.71	-2.86
	2	-4.55	-6.82	-4.35	-8.70	-2.13	-8.51	-6.38	-14.89	0.00	-8.89	6.52	-4.35
	3	-6.56	-11.48	-4.84	-9.68	-3.17	-7.94	-9.52	-19.05	4.84	-8.06	6.35	-3.17
	4	-10.87	-17.39	-6.38	-10.64	0.00	-6.52	-8.70	-17.39	8.51	-10.64	8.70	-2.17
	5	-13.43	-25.37	-7.14	-12.86	-1.43	-8.57	-7.25	-14.49	11.43	-12.86	7.14	-5.71
	6	10.14	10.14	7.14	5.71	4.48	4.48	5.88	5.88	-15.71	2.86	-5.80	1.45
	7	12.50	14.58	6.52	6.52	6.67	6.67	6.38	6.38	-15.22	2.17	-6.52	2.17
	8	9.38	17.19	6.25	4.69	6.45	6.45	7.81	7.81	-10.94	7.81	-4.76	1.59
	9	12.50	***20.83***	6.25	6.25	6.25	6.25	8.51	6.38	-8.51	8.51	-8.51	0.00
	10	10.00	***21.43***	7.14	5.71	2.90	4.35	7.35	10.29	-11.94	8.96	-8.57	1.43
M	11	4.76	9.52	2.27	6.82	7.32	12.20	0.00	-2.33	-2.27	0.00	0.00	4.88
E	12	4.44	6.67	3.23	8.60	6.45	11.83	3.26	6.52	-4.55	-2.27	-4.40	5.49
A	13	7.14	11.90	4.65	9.30	6.98	9.30	2.38	2.38	0.00	4.65	0.00	7.32
S	14	0.00	-4.65	-2.44	-14.63	-4.76	-14.29	-7.32	-19.51	-2.44	-4.88	2.33	-9.30
U	15	-1.09	-4.35	-1.09	-11.96	-5.68	-15.91	-4.49	-13.48	-4.30	-4.30	2.15	-7.53
R	16	0.00	-2.33	2.33	-6.98	2.33	-6.98	-2.33	-9.30	-6.98	0.00	0.00	-6.67
E	Right												
M	1	-2.99	-8.96	-5.88	-7.35	-5.80	-14.49	-7.46	-16.42	2.99	-7.46	4.29	-2.86
E	2	-4.35	-10.87	-6.52	-6.52	-6.38	-12.77	-13.64	-25.00	2.22	-8.89	4.26	-2.13
N	3	-6.45	-14.52	-6.25	-6.25	-4.69	-10.94	-9.68	-19.35	3.23	-9.68	6.15	-1.54
T	4	-10.42	-20.83	-8.33	-10.42	-4.17	-10.42	-8.33	-16.67	6.38	-12.77	6.25	-4.17
	5	-14.71	-27.94	-10.14	-13.04	-2.86	-11.43	-7.04	-15.49	10.14	-13.04	8.57	-4.29
	6	4.62	7.69	0.00	-1.49	1.54	3.08	3.13	7.81	-8.96	4.48	-6.06	3.03
	7	4.44	8.89	0.00	-4.44	0.00	2.17	0.00	4.65	-10.64	4.26	-4.35	2.17
	8	8.06	14.52	0.00	-3.28	0.00	1.59	-1.69	3.39	-6.25	6.25	-6.45	0.00
	9	8.70	17.39	4.44	0.00	0.00	0.00	2.27	6.82	-4.26	8.51	-11.36	0.00
	10	8.82	17.65	4.55	3.03	0.00	1.47	6.06	10.61	-7.25	8.70	-8.96	1.49
	11	5.00	5.00	4.88	7.32	4.65	13.95	-2.44	2.44	-11.90	-2.38	-7.32	4.88
	12	5.68	4.55	4.35	9.78	3.23	10.75	0.00	4.40	-7.69	0.00	-5.56	5.56
	13	7.50	10.00	2.38	7.14	2.44	9.76	-7.69	-5.13	-7.14	0.00	-7.32	4.88
	14	-9.52	-14.29	-9.76	-19.51	-9.52	-19.05	-9.52	-19.05	9.52	-4.76	6.98	-6.98
	15	-7.69	-12.09	-10.23	-19.32	-7.87	-21.35	-5.75	-14.94	6.59	-4.40	6.52	-6.52
	16	-4.65	-9.30	-9.52	-16.67	-6.82	-18.18	-7.14	-14.29	4.65	-2.33	4.44	-6.67

Table 3.9 The measurement table for subject 1 with highlighted percentage contraction values

Inner HH-HD	HH-HU	Nipple HH-HD	HH-HU	Outer UU-UH	UU-UD	Upper UU-UH	UU-UD	Inner UU-UH	UU-UD	Nipple UU-UH	UU-UD
0.00	-5.80	2.94	0.00	4.41	4.41	0.00	5.80	2.86	7.14	4.48	7.46
2.13	-6.38	4.08	-2.04	4.44	6.67	2.17	8.70	4.26	8.51	6.52	8.70
-1.59	-7.94	4.55	-3.03	8.20	11.48	1.59	9.52	3.13	6.25	6.67	11.67
-2.13	-10.64	4.08	-2.04	8.70	17.39	2.17	10.87	4.26	6.38	-2.22	11.11
-2.78	-8.33	5.63	-2.82	11.59	***26.09***	1.41	9.86	2.82	5.63	7.25	11.59
-2.99	1.49	-7.81	1.56	4.29	-17.14	-2.90	-11.59	0.00	-2.94	-3.13	-10.94
-2.22	2.22	-6.98	4.65	2.17	-17.39	0.00	-10.87	0.00	-2.17	-4.76	-14.29
-1.61	3.23	-10.17	5.08	-1.59	-19.05	-1.61	-9.68	0.00	-3.13	-3.39	-13.56
0.00	6.25	-9.09	-4.55	-4.26	-23.40	-2.13	-12.77	-2.08	-4.17	-2.33	-11.63
-2.86	5.71	-9.68	4.84	-7.25	-24.64	-4.41	-14.71	-2.86	-7.14	-4.62	-15.38
0.00	9.52	-7.14	4.76	2.33	-11.63	-2.44	-4.88	--2.38	-2.38	2.50	-5.00
-3.19	8.51	-10.47	4.65	2.25	-8.99	-5.49	-9.89	-3.19	-6.38	-4.65	-9.30
-2.33	9.30	-9.52	4.76	0.00	-12.20	-4.88	-9.76	-2.27	-4.55	-2.56	-7.69
2.38	-11.90	4.88	-4.88	7.32	4.88	4.76	9.52	6.98	11.63	4.88	4.88
0.00	-13.48	6.59	-3.30	4.35	1.09	4.40	5.49	6.59	8.79	5.56	5.56
-2.38	-11.90	4.65	0.00	4.76	-2.38	0.00	4.65	6.98	9.30	5.00	2.50
2.90	-7.25	1.47	-7.35	7.25	11.59	1.45	7.25	4.41	10.29	3.03	7.58
2.17	-6.52	0.00	-8.70	6.52	10.87	0.00	8.51	4.35	8.70	4.55	9.09
3.17	-6.35	4.76	-7.94	6.45	14.52	0.00	7.81	6.45	8.06	4.92	9.84
4.17	-4.17	4.17	-6.25	8.51	19.15	4.08	12.24	8.33	10.42	4.26	8.51
1.47	-5.88	5.80	-7.25	11.59	***24.64***	2.86	14.29	7.35	11.76	5.97	11.94
-1.49	1.49	-6.06	3.03	-5.88	-14.71	-4.55	-12.12	-2.94	-5.88	-6.15	-13.85
0.00	2.17	-4.44	2.22	-6.38	-14.89	-2.17	-10.87	-2.13	-6.38	-4.55	-13.64
0.00	1.59	-6.45	4.84	-9.52	-17.46	-3.28	-11.48	-1.56	-4.69	-6.56	-14.75
0.00	4.35	-4.44	6.67	-8.70	-19.57	-4.55	-15.91	-2.13	-6.38	-6.82	-15.91
-1.47	2.94	-4.48	5.97	-8.70	-20.29	-6.06	-16.67	-1.45	-7.25	-6.06	-13.64
-2.38	4.76	-7.50	2.50	-2.38	-16.67	-4.88	-9.76	-2.33	-4.65	-4.88	-12.20
-3.26	6.52	-6.67	4.44	-2.25	-11.24	-6.67	-11.11	-2.15	-6.45	-4.60	-10.34
-2.44	7.32	-7.32	4.88	-2.44	-9.76	-9.76	-14.63	0.00	-4.76	-5.13	-10.26
4.76	-11.90	4.65	-9.30	2.38	11.90	9.30	11.63	4.76	9.52	2.38	4.76
3.37	-11.24	4.49	-7.87	1.09	6.52	5.49	8.79	6.67	11.11	3.41	5.68
4.65	-9.30	2.33	-4.65	-2.33	2.33	4.65	6.98	6.98	11.63	0.00	2.38

Table 3.9 The measurement table for subject 1 with highlighted percentage contraction values (cont'd)

		Outer DD-DH	DD-DU	Upper DD-DH	DD-DU	Inner DD-DH	DD-DU	Nipple DD-DH	DD-DU	Outer HH-HD	HH-HU	Upper HH-HD	HH-HU
	Left												
	1	-2.99	-5.97	-2.90	-7.25	-2.86	-7.14	-4.35	-8.70	0.00	-8.70	5.71	-2.86
	2	-4.55	-6.82	-4.35	-8.70	-2.13	-8.51	-6.38	-14.89	0.00	-8.89	6.52	-4.35
	3	-6.56	-11.48	-4.84	-9.68	-3.17	-7.94	-9.52	-19.05	4.84	-8.06	6.35	-3.17
	4	-10.87	-17.39	-6.38	-10.64	0.00	-6.52	-8.70	-17.39	8.51	-10.64	8.70	-2.17
	5	-13.43	***-25.37***	-7.14	-12.86	-1.43	-8.57	-7.25	-14.49	11.43	-12.86	7.14	-5.71
	6	10.14	10.14	7.14	5.71	4.48	4.48	5.88	5.88	-15.71	2.86	-5.80	1.45
	7	12.50	14.58	6.52	6.52	6.67	6.67	6.38	6.38	-15.22	2.17	-6.52	2.17
	8	9.38	17.19	6.25	4.69	6.45	6.45	7.81	7.81	-10.94	7.81	-4.76	1.59
	9	12.50	20.83	6.25	6.25	6.25	6.25	8.51	6.38	-8.51	8.51	-8.51	0.00
	10	10.00	21.43	7.14	5.71	2.90	4.35	7.35	10.29	-11.94	8.96	-8.57	1.43
M	11	4.76	9.52	2.27	6.82	7.32	12.20	0.00	-2.33	-2.27	0.00	0.00	4.88
E	12	4.44	6.67	3.23	8.60	6.45	11.83	3.26	6.52	-4.55	-2.27	-4.40	5.49
A	13	7.14	11.90	4.65	9.30	6.98	9.30	2.38	2.38	0.00	4.65	0.00	7.32
S	14	0.00	-4.65	-2.44	-14.63	-4.76	-14.29	-7.32	-19.51	-2.44	-4.88	2.33	-9.30
U	15	-1.09	-4.35	-1.09	-11.96	-5.68	-15.91	-4.49	-13.48	-4.30	-4.30	2.15	-7.53
R	16	0.00	-2.33	2.33	-6.98	2.33	-6.98	-2.33	-9.30	-6.98	0.00	0.00	-6.67
E	Right												
M	1	-2.99	-8.96	-5.88	-7.35	-5.80	-14.49	-7.46	-16.42	2.99	-7.46	4.29	-2.86
E	2	-4.35	-10.87	-6.52	-6.52	-6.38	-12.77	-13.64	***-25.00***	2.22	-8.89	4.26	-2.13
N	3	-6.45	-14.52	-6.25	-6.25	-4.69	-10.94	-9.68	-19.35	3.23	-9.68	6.15	-1.54
T	4	-10.42	***-20.83***	-8.33	-10.42	-4.17	-10.42	-8.33	-16.67	6.38	-12.77	6.25	-4.17
	5	-14.71	***-27.94***	-10.14	-13.04	-2.86	-11.43	-7.04	-15.49	10.14	-13.04	8.57	-4.29
	6	4.62	7.69	0.00	-1.49	1.54	3.08	3.13	7.81	-8.96	4.48	-6.06	3.03
	7	4.44	8.89	0.00	-4.44	0.00	2.17	0.00	4.65	-10.64	4.26	-4.35	2.17
	8	8.06	14.52	0.00	-3.28	0.00	1.59	-1.69	3.39	-6.25	6.25	-6.45	0.00
	9	8.70	17.39	4.44	0.00	0.00	0.00	2.27	6.82	-4.26	8.51	-11.36	0.00
	10	8.82	17.65	4.55	3.03	0.00	1.47	6.06	10.61	-7.25	8.70	-8.96	1.49
	11	5.00	5.00	4.88	7.32	4.65	13.95	-2.44	2.44	-11.90	-2.38	-7.32	4.88
	12	5.68	4.55	4.35	9.78	3.23	10.75	0.00	4.40	-7.69	0.00	-5.56	5.56
	13	7.50	10.00	2.38	7.14	2.44	9.76	-7.69	-5.13	-7.14	0.00	-7.32	4.88
	14	-9.52	-14.29	-9.76	-19.51	-9.52	-19.05	-9.52	-19.05	9.52	-4.76	6.98	-6.98
	15	-7.69	-12.09	-10.23	-19.32	-7.87	***-21.35***	-5.75	-14.94	6.59	-4.40	6.52	-6.52
	16	-4.65	-9.30	-9.52	-16.67	-6.82	-18.18	-7.14	-14.29	4.65	-2.33	4.44	-6.67

Table 3.10 The measurement table for subject 1 with highlighted percentage expansion values

Inner HH-HD	HH-HU	Nipple HH-HD	HH-HU	Outer UU-UH	UU-UD	Upper UU-UH	UU-UD	Inner UU-UH	UU-UD	Nipple UU-UH	UU-UD
0.00	-5.80	2.94	0.00	4.41	4.41	0.00	5.80	2.86	7.14	4.48	7.46
2.13	-6.38	4.08	-2.04	4.44	6.67	2.17	8.70	4.26	8.51	6.52	8.70
-1.59	-7.94	4.55	-3.03	8.20	11.48	1.59	9.52	3.13	6.25	6.67	11.67
-2.13	-10.64	4.08	-2.04	8.70	17.39	2.17	10.87	4.26	6.38	-2.22	11.11
-2.78	-8.33	5.63	-2.82	11.59	26.09	1.41	9.86	2.82	5.63	7.25	11.59
-2.99	1.49	-7.81	1.56	4.29	-17.14	-2.90	-11.59	0.00	-2.94	-3.13	-10.94
-2.22	2.22	-6.98	4.65	2.17	-17.39	0.00	-10.87	0.00	-2.17	-4.76	-14.29
-1.61	3.23	-10.17	5.08	-1.59	-19.05	-1.61	-9.68	0.00	-3.13	-3.39	-13.56
0.00	6.25	-9.09	-4.55	-4.26	***-23.40***	-2.13	-12.77	-2.08	-4.17	-2.33	-11.63
-2.86	5.71	-9.68	4.84	-7.25	***-24.64***	-4.41	-14.71	-2.86	-7.14	-4.62	-15.38
0.00	9.52	-7.14	4.76	2.33	-11.63	-2.44	-4.88	-2.38	-2.38	2.50	-5.00
-3.19	8.51	-10.47	4.65	2.25	-8.99	-5.49	-9.89	-3.19	-6.38	-4.65	-9.30
-2.33	9.30	-9.52	4.76	0.00	-12.20	-4.88	-9.76	-2.27	-4.55	-2.56	-7.69
2.38	-11.90	4.88	-4.88	7.32	4.88	4.76	9.52	6.98	11.63	4.88	4.88
0.00	-13.48	6.59	-3.30	4.35	1.09	4.40	5.49	6.59	8.79	5.56	5.56
-2.38	-11.90	4.65	0.00	4.76	-2.38	0.00	4.65	6.98	9.30	5.00	2.50
2.90	-7.25	1.47	-7.35	7.25	11.59	1.45	7.25	4.41	10.29	3.03	7.58
2.17	-6.52	0.00	-8.70	6.52	10.87	0.00	8.51	4.35	8.70	4.55	9.09
3.17	-6.35	4.76	-7.94	6.45	14.52	0.00	7.81	6.45	8.06	4.92	9.84
4.17	-4.17	4.17	-6.25	8.51	19.15	4.08	12.24	8.33	10.42	4.26	8.51
1.47	-5.88	5.80	-7.25	11.59	24.64	2.86	14.29	7.35	11.76	5.97	11.94
-1.49	1.49	-6.06	3.03	-5.88	-14.71	-4.55	-12.12	-2.94	-5.88	-6.15	-13.85
0.00	2.17	-4.44	2.22	-6.38	-14.89	-2.17	-10.87	-2.13	-6.38	-4.55	-13.64
0.00	1.59	-6.45	4.84	-9.52	-17.46	-3.28	-11.48	-1.56	-4.69	-6.56	-14.75
0.00	4.35	-4.44	6.67	-8.70	-19.57	-4.55	-15.91	-2.13	-6.38	-6.82	-15.91
-1.47	2.94	-4.48	5.97	-8.70	***-20.29***	-6.06	-16.67	-1.45	-7.25	-6.06	-13.64
-2.38	4.76	-7.50	2.50	-2.38	-16.67	-4.88	-9.76	-2.33	-4.65	-4.88	-12.20
-3.26	6.52	-6.67	4.44	-2.25	-11.24	-6.67	-11.11	-2.15	-6.45	-4.60	-10.34
-2.44	7.32	-7.32	4.88	-2.44	-9.76	-9.76	-14.63	0.00	-4.76	-5.13	-10.26
4.76	-11.90	4.65	-9.30	2.38	11.90	9.30	11.63	4.76	9.52	2.38	4.76
3.37	-11.24	4.49	-7.87	1.09	6.52	5.49	8.79	6.67	11.11	3.41	5.68
4.65	-9.30	2.33	-4.65	-2.33	2.33	4.65	6.98	6.98	11.63	0.00	2.38

Table 3.10 **The measurement table for subject 1 with highlighted percentage expansion values (cont'd)**

		Outer		Upper		Inner		Nipple		Outer		Upper	
		DD-DH	DD-DU	DD-DH	DD-DU	DD-DH	DD-DU	DD-DH	DD-DU	HH-HD	HH-HU	HH-HD	HH-HU
	Left												
	1	0.00	-7.14	-8.70	-14.49	-4.35	-5.80	-1.43	-8.57	1.45	-5.80	5.48	-2.74
	2	0.00	-4.08	-10.64	-14.89	-6.25	-6.25	-2.08	-12.50	2.04	-6.12	6.00	-4.00
	3	-1.56	-9.38	-9.84	-16.39	-6.35	-6.35	-4.92	-13.11	3.23	-8.06	6.06	-3.03
	4	-2.08	-12.50	-13.33	-22.22	-8.89	-11.11	-2.22	-13.33	6.67	-11.11	10.20	-4.08
	5	-5.63	-18.31	-10.29	-22.06	-7.46	-10.45	-2.90	-10.14	7.25	-14.49	8.45	-7.04
	6	4.48	13.43	1.52	12.12	4.41	4.41	7.58	12.12	-7.35	13.24	-2.99	8.96
	7	4.44	15.56	2.22	11.11	4.35	6.52	8.89	15.56	-6.38	14.89	-4.35	8.70
	8	4.92	19.67	1.67	10.00	6.45	9.68	8.20	16.39	-6.45	14.52	-6.67	6.67
	9	4.44	17.78	4.44	11.11	4.35	8.70	13.33	20.00	-4.35	15.22	-11.63	4.65
	10	5.88	***20.59***	4.55	12.12	5.80	10.14	10.45	19.40	-5.97	16.42	-12.70	4.76
M	11	4.76	7.14	-2.38	0.00	2.38	9.52	-2.50	2.50	-2.38	0.00	-2.33	2.33
E	12	5.56	6.67	0.00	5.56	4.35	13.04	3.41	11.36	-3.33	0.00	-5.49	5.49
A	13	4.76	7.14	0.00	7.50	4.65	13.95	2.50	12.50	-2.33	4.65	-7.14	7.14
S	14	0.00	-4.76	-12.50	-15.00	-4.76	-11.90	4.76	-4.76	0.00	0.00	6.98	-4.65
U	15	-3.23	-3.23	-7.78	-13.33	-4.44	-12.22	2.20	-6.59	1.08	3.23	5.43	-4.35
R	16	-2.38	-2.38	-5.00	-5.00	-2.50	-12.50	2.44	-4.88	0.00	4.88	4.88	-2.44
E	Right												
M	1	-4.41	-5.88	-8.70	-15.94	-2.90	-4.35	-4.35	-8.70	1.45	-5.80	4.29	-4.29
E	2	-4.26	-4.26	-13.04	-21.74	-2.13	-4.26	0.00	-4.26	2.08	-6.25	4.26	-4.26
N	3	-6.35	-9.52	-14.29	-25.40	-3.17	-6.35	-4.76	-9.52	1.56	-7.81	4.69	-6.25
T	4	-6.12	-12.24	-19.15	-31.91	2.04	-4.08	-4.08	-10.20	4.00	-12.00	6.38	-6.38
	5	-10.00	-18.57	-20.29	-34.78	-1.47	-7.35	-4.35	-8.70	5.63	-14.08	8.45	-7.04
	6	7.46	17.91	0.00	8.82	3.08	6.15	9.52	15.87	-2.94	10.29	-2.90	7.25
	7	6.52	17.39	0.00	6.52	2.22	4.44	9.30	13.95	-2.13	12.77	-2.08	4.17
	8	8.06	19.35	4.84	9.68	3.28	6.56	9.84	13.11	-3.13	10.94	-6.56	1.64
	9	6.67	15.56	8.70	10.87	2.22	6.67	9.09	15.91	-2.08	12.50	-8.89	0.00
	10	8.70	17.39	10.29	13.24	2.90	7.25	9.09	15.15	-1.41	14.08	-10.45	4.48
	11	2.38	7.14	0.00	0.00	4.76	9.52	7.50	10.00	-4.65	4.65	-2.33	2.33
	12	2.20	5.49	5.38	8.60	3.23	12.90	6.59	13.19	-3.23	3.23	-5.43	4.35
	13	4.88	9.76	4.76	11.90	2.44	14.63	2.44	9.76	-2.33	4.65	-6.98	4.65
	14	-2.33	-2.33	-16.67	-28.57	-4.76	-14.29	-2.38	-11.90	6.98	-2.33	7.32	-9.76
	15	-2.17	-2.17	-15.73	-25.84	-2.25	-11.24	-2.30	-9.20	4.35	-2.17	4.40	-6.59
	16	-2.33	2.33	-12.20	-21.95	2.33	-6.98	-2.38	-7.14	0.00	0.00	0.00	-7.50

Table 3.11 **The measurement table for subject 2 with highlighted percentage contraction values**

Inner HH-HD	HH-HU	Nipple HH-HD	HH-HU	Outer UU-UH	UU-UD	Upper UU-UH	UU-UD	Inner UU-UH	UU-UD	Nipple UU-UH	UU-UD
4.17	0.00	0.00	-4.29	7.04	9.86	4.29	11.43	0.00	4.41	5.56	8.33
4.08	0.00	-2.04	-6.12	8.00	10.00	4.08	10.20	-2.13	2.13	6.00	8.00
3.13	0.00	-3.08	-6.15	6.25	12.50	6.25	12.50	-1.59	3.17	7.58	9.09
0.00	-4.35	-4.26	-8.51	8.51	19.15	4.26	12.77	-2.22	0.00	6.25	6.25
0.00	-5.80	1.43	-5.71	11.59	***21.74***	5.80	13.04	-4.62	-1.54	2.82	5.63
-1.47	4.41	-21.54	6.15	-10.45	-22.39	-8.96	-17.91	-5.88	-11.76	-12.31	-26.15
0.00	6.25	-32.56	4.65	-8.51	-21.28	-8.70	-19.57	-6.38	-10.64	-15.56	-35.56
-1.56	6.25	-31.03	8.62	-7.94	-19.05	-10.00	-21.67	-7.69	-12.31	-16.39	-37.70
0.00	8.33	-25.00	6.82	-10.87	-21.74	-11.63	-27.91	-10.42	-16.67	-17.78	-37.78
-1.45	7.25	-17.19	7.81	-13.04	-21.74	-12.31	-29.23	-11.59	-17.39	-15.15	-28.79
-2.27	6.82	-35.00	0.00	-4.76	-7.14	-2.38	-7.14	-6.67	-6.67	-6.98	-20.93
-3.19	8.51	-16.28	5.81	-2.22	-6.67	-6.74	-13.48	-11.96	-15.22	-8.99	-15.73
-2.27	11.36	-17.07	4.88	-4.76	-7.14	-4.88	-12.20	-13.95	-18.60	-9.52	-23.81
4.76	-4.76	-4.76	-4.76	2.38	2.38	2.38	7.14	2.44	4.88	2.44	-7.32
5.49	-4.40	-4.35	-4.35	-1.06	-2.13	1.09	1.09	1.12	2.25	1.08	-6.45
0.00	-5.00	-14.63	-2.44	-4.76	-7.14	0.00	-4.76	2.44	0.00	0.00	-9.30
-2.90	-4.35	0.00	-4.35	4.41	4.41	2.82	11.27	-1.47	4.41	2.90	2.90
-2.13	-4.26	2.08	-2.08	6.38	6.38	2.08	8.33	-2.17	4.35	8.51	0.00
-3.17	-4.76	3.08	-6.15	6.35	9.52	3.08	10.77	0.00	4.84	4.62	4.62
-2.08	-4.17	4.00	-4.00	8.33	14.58	4.08	12.24	2.13	4.26	4.17	2.08
-2.90	-4.35	1.43	-5.71	8.70	18.84	4.29	15.71	1.49	4.48	4.41	5.88
-3.08	4.62	-7.81	10.94	-9.72	-18.06	-5.88	-10.29	-8.96	-14.93	-10.77	-21.54
-6.82	2.27	-9.09	9.09	-8.16	-16.33	-4.26	-6.38	-11.11	-15.56	-11.11	-24.44
-3.28	3.28	-10.00	10.00	-9.09	-15.15	-6.45	-11.29	-9.68	-14.52	-14.75	-27.87
0.00	6.52	-9.30	9.30	-10.20	-16.33	-6.67	-15.56	-6.38	-12.77	-16.28	-27.91
0.00	7.25	-7.69	10.77	-11.11	-16.67	-7.46	-16.42	-4.23	-9.86	-12.50	-18.75
-2.38	4.76	-10.00	5.00	-2.33	-9.30	0.00	-2.33	-4.65	-6.98	-7.14	-19.05
-3.30	6.59	-5.56	10.00	-2.13	-6.38	-4.40	-9.89	-5.32	-8.51	-10.23	-18.18
-7.50	7.50	-10.00	10.00	-2.33	-6.98	-4.76	-11.90	-9.76	-12.20	-9.76	-21.95
-2.38	-7.14	0.00	-6.82	2.33	4.65	2.33	11.63	-5.00	0.00	-2.38	-2.38
-1.11	-6.67	1.11	-5.56	-1.06	-1.06	0.00	8.79	-2.30	0.00	0.00	-1.15
0.00	-4.65	0.00	-2.27	-4.55	-4.55	0.00	6.82	0.00	-2.38	-2.33	-2.33

Table 3.11 **The measurement table for subject 2 with highlighted percentage contraction values (cont'd)**

		Outer DD-DH	DD-DU	Upper DD-DH	DD-DU	Inner DD-DH	DD-DU	Nipple DD-DH	DD-DU	Outer HH-HD	HH-HU	Upper HH-HD	HH-HU
	Left												
	1	0.00	-7.14	-8.70	-14.49	-4.35	-5.80	-1.43	-8.57	1.45	-5.80	5.48	-2.74
	2	0.00	-4.08	-10.64	-14.89	-6.25	-6.25	-2.08	-12.50	2.04	-6.12	6.00	-4.00
	3	-1.56	-9.38	-9.84	-16.39	-6.35	-6.35	-4.92	-13.11	3.23	-8.06	6.06	-3.03
	4	-2.08	-12.50	-13.33	***-22.22***	-8.89	-11.11	-2.22	-13.33	6.67	-11.11	10.20	-4.08
	5	-5.63	-18.31	-10.29	***-22.06***	-7.46	-10.45	-2.90	-10.14	7.25	-14.49	8.45	-7.04
	6	4.48	13.43	1.52	12.12	4.41	4.41	7.58	12.12	-7.35	13.24	-2.99	8.96
	7	4.44	15.56	2.22	11.11	4.35	6.52	8.89	15.56	-6.38	14.89	-4.35	8.70
	8	4.92	19.67	1.67	10.00	6.45	9.68	8.20	16.39	-6.45	14.52	-6.67	6.67
	9	4.44	17.78	4.44	11.11	4.35	8.70	13.33	20.00	-4.35	15.22	-11.63	4.65
	10	5.88	20.59	4.55	12.12	5.80	10.14	10.45	19.40	-5.97	16.42	-12.70	4.76
M	11	4.76	7.14	-2.38	0.00	2.38	9.52	-2.50	2.50	-2.38	0.00	-2.33	2.33
E	12	5.56	6.67	0.00	5.56	4.35	13.04	3.41	11.36	-3.33	0.00	-5.49	5.49
A	13	4.76	7.14	0.00	7.50	4.65	13.95	2.50	12.50	-2.33	4.65	-7.14	7.14
S	14	0.00	-4.76	-12.50	-15.00	-4.76	-11.90	4.76	-4.76	0.00	0.00	6.98	-4.65
U	15	-3.23	-3.23	-7.78	-13.33	-4.44	-12.22	2.20	-6.59	1.08	3.23	5.43	-4.35
R	16	-2.38	-2.38	-5.00	-5.00	-2.50	-12.50	2.44	-4.88	0.00	4.88	4.88	-2.44
E	Right												
M	1	-4.41	-5.88	-8.70	-15.94	-2.90	-4.35	-4.35	-8.70	1.45	-5.80	4.29	-4.29
E	2	-4.26	-4.26	-13.04	***-21.74***	-2.13	-4.26	0.00	-4.26	2.08	-6.25	4.26	-4.26
N	3	-6.35	-9.52	-14.29	***-25.40***	-3.17	-6.35	-4.76	-9.52	1.56	-7.81	4.69	-6.25
T	4	-6.12	-12.24	-19.15		2.04	-4.08	-4.08	-10.20	4.00	-12.00	6.38	-6.38
	5	-10.00	-18.57	***-20.29***		-1.47	-7.35	-4.35	-8.70	5.63	-14.08	8.45	-7.04
	6	7.46	17.91	0.00	8.82	3.08	6.15	9.52	15.87	-2.94	10.29	-2.90	7.25
	7	6.52	17.39	0.00	6.52	2.22	4.44	9.30	13.95	-2.13	12.77	-2.08	4.17
	8	8.06	19.35	4.84	9.68	3.28	6.56	9.84	13.11	-3.13	10.94	-6.56	1.64
	9	6.67	15.56	8.70	10.87	2.22	6.67	9.09	15.91	-2.08	12.50	-8.89	0.00
	10	8.70	17.39	10.29	13.24	2.90	7.25	9.09	15.15	-1.41	14.08	-10.45	4.48
	11	2.38	7.14	0.00	0.00	4.76	9.52	7.50	10.00	-4.65	4.65	-2.33	2.33
	12	2.20	5.49	5.38	8.60	3.23	12.90	6.59	13.19	-3.23	3.23	-5.43	4.35
	13	4.88	9.76	4.76	11.90	2.44	14.63	2.44	9.76	-2.33	4.65	-6.98	4.65
	14	-2.33	-2.33	-16.67	***-28.57***	-4.76	-14.29	-2.38	-11.90	6.98	-2.33	7.32	-9.76
	15	-2.17	-2.17	-15.73	***-25.84***	-2.25	-11.24	-2.30	-9.20	4.35	-2.17	4.40	-6.59
	16	-2.33	2.33	-12.20	***-21.95***	2.33	-6.98	-2.38	-7.14	0.00	0.00	0.00	-7.50

Table 3.12 **The measurement table for subject 2 with highlighted percentage expansion values**

Inner HH-HD	HH-HU	Nipple HH-HD	HH-HU	Outer UU-UH	UU-UD	Upper UU-UH	UU-UD	Inner UU-UH	UU-UD	Nipple UU-UH	UU-UD
4.17	0.00	0.00	-4.29	7.04	9.86	4.29	11.43	0.00	4.41	5.56	8.33
4.08	0.00	-2.04	-6.12	8.00	10.00	4.08	10.20	-2.13	2.13	6.00	8.00
3.13	0.00	-3.08	-6.15	6.25	12.50	6.25	12.50	-1.59	3.17	7.58	9.09
0.00	-4.35	-4.26	-8.51	8.51	19.15	4.26	12.77	-2.22	0.00	6.25	6.25
0.00	-5.80	1.43	-5.71	11.59	21.74	5.80	13.04	-4.62	-1.54	2.82	5.63
-1.47	4.41	***-21.54***	6.15	-10.45	***-22.39***	-8.96	-17.91	-5.88	-11.76	-12.31	***-26.15***
0.00	6.25	[illegible]	4.65	-8.51	***-21.28***	-8.70	-19.57	-6.38	-10.64	-15.56	[illegible]
-1.56	6.25	[illegible]	8.62	-7.94	-19.05	-10.00	***-21.67***	-7.69	-12.31	-16.39	[illegible]
0.00	8.33	***-25.00***	6.82	-10.87	***-21.74***	-11.63	***-27.91***	-10.42	-16.67	-17.78	[illegible]
-1.45	7.25	-17.19	7.81	-13.04	***-21.74***	-12.31	***-29.23***	-11.59	-17.39	-15.15	***-28.79***
-2.27	6.82	[illegible]	0.00	-4.76	-7.14	-2.38	-7.14	-6.67	-6.67	-6.98	***-20.93***
-3.19	8.51	-16.28	5.81	-2.22	-6.67	-6.74	-13.48	-11.96	-15.22	-8.99	-15.73
-2.27	11.36	-17.07	4.88	-4.76	-7.14	-4.88	-12.20	-13.95	-18.60	-9.52	***-23.81***
4.76	-4.76	-4.76	-4.76	2.38	2.38	2.38	7.14	2.44	4.88	2.44	-7.32
5.49	-4.40	-4.35	-4.35	-1.06	-2.13	1.09	1.09	1.12	2.25	1.08	-6.45
0.00	-5.00	-14.63	-2.44	-4.76	-7.14	0.00	-4.76	2.44	0.00	0.00	-9.30
-2.90	-4.35	0.00	-4.35	4.41	4.41	2.82	11.27	-1.47	4.41	2.90	2.90
-2.13	-4.26	2.08	-2.08	6.38	6.38	2.08	8.33	-2.17	4.35	8.51	0.00
-3.17	-4.76	3.08	-6.15	6.35	9.52	3.08	10.77	0.00	4.84	4.62	4.62
-2.08	-4.17	4.00	-4.00	8.33	14.58	4.08	12.24	2.13	4.26	4.17	2.08
-2.90	-4.35	1.43	-5.71	8.70	18.84	4.29	15.71	1.49	4.48	4.41	5.88
-3.08	4.62	-7.81	10.94	-9.72	-18.06	-5.88	-10.29	-8.96	-14.93	-10.77	***-21.54***
-6.82	2.27	-9.09	9.09	-8.16	-16.33	-4.26	-6.38	-11.11	-15.56	-11.11	***-24.44***
-3.28	3.28	-10.00	10.00	-9.09	-15.15	-6.45	-11.29	-9.68	-14.52	-14.75	***-27.87***
0.00	6.52	-9.30	9.30	-10.20	-16.33	-6.67	-15.56	-6.38	-12.77	-16.28	***-27.91***
0.00	7.25	-7.69	10.77	-11.11	-16.67	-7.46	-16.42	-4.23	-9.86	-12.50	-18.75
-2.38	4.76	-10.00	5.00	-2.33	-9.30	0.00	-2.33	-4.65	-6.98	-7.14	-19.05
-3.30	6.59	-5.56	10.00	-2.13	-6.38	-4.40	-9.89	-5.32	-8.51	-10.23	-18.18
-7.50	7.50	-10.00	10.00	-2.33	-6.98	-4.76	-11.90	-9.76	-12.20	-9.76	***-21.95***
-2.38	-7.14	0.00	-6.82	2.33	4.65	2.33	11.63	-5.00	0.00	-2.38	-2.38
-1.11	-6.67	1.11	-5.56	-1.06	-1.06	0.00	8.79	-2.30	0.00	0.00	-1.15
0.00	-4.65	0.00	-2.27	-4.55	-4.55	0.00	6.82	0.00	-2.38	-2.33	-2.33

Table 3.12 **The measurement table for subject 2 with highlighted percentage expansion values (cont'd)**

	Side	Site	Contraction	Expansion	No Distortion
Subject 1	left	outer	46	46	8
	left	upper	47	46	7
	left	inner	45	47	8
	left	nipple	47	50	3
	right	outer	46	52	2
	right	upper	39	53	8
	right	inner	45	46	9
	right	nipple	42	54	4
Subject 2	left	outer	44	48	8
	left	upper	44	52	4
	left	inner	39	50	11
	left	nipple	40	57	3
	right	outer	46	52	2
	right	upper	42	49	9
	right	inner	34	58	7
	right	nipple	40	54	6

Table 3.13 The percentage frequency of contraction, expansion and no distortion in the four sites on each breast of the two subjects

Chapter 4

POSTURE DISTORTION - THE INITIAL STAGES OF THE MAIN STUDY

Chapter 4

POSTURE DISTORTION - THE INITIAL STAGES OF THE MAIN STUDY

4.1 INTRODUCTION

The preliminary study demonstrated posture distortion in two subjects comparable to the posture distortion in a bite mark case. The research compared the posture distortion percentage values of the left and right breasts, quantified posture distortion, compared distortion in the four breast sites, studied the influence of arm movement on distortion and demonstrated patterns of distortion. The preliminary study produced general conclusions which provided the basis for further research.

4.2. AIMS

The initial stages of the main study of posture distortion in the female breast reported in this Chapter, utilised the same techniques of creation and photography of study marks as described in Chapter 3 in a larger number of subjects of varying ages and anatomical proportions.

The aims of the initial stages of the main study were to research posture distortion in the female breast utilising 20 subjects. Specifically, the objectives were to quantify posture distortion in the female breast, to compare posture distortion in multiple axes of the four breast sites and to study the influence of arm movement and in addition to assess the influence of age, bust size, cup size and ptosis on posture distortion.

4.3 MATERIALS AND METHODS

4.3.1 Subjects

The initial stages of the main study of posture distortion in the female breast were undertaken using 20 subjects. The subjects were selected on the basis that they represented a range of age, bust size and cup size in a sample of the adult female population. Subjects A and B of the main study were subjects 1 and 2 respectively of the preliminary study; the photographic prints were re-used in the main study.

4.3.2. Creation and photography of study marks

The photographic equipment, the extension arm with measurement frame and the die stamp which were described in the preliminary study were utilised in the initial stages of the main study. The same personnel conducted the creation and photography of the study marks in the main study in exactly the same manner as in the preliminary study. Therefore, the initial sequence of frontal and lateral views of each subject were followed by study mark views of the four sites on each breast. The frontal views were photographed with the arms vertically down, arms horizontal and arms vertically up as illustrated in Figure 4.1 The lateral view was photographed with arms vertically down as illustrated in Figure 4.2. The photographic sequence of the breast sites described in the preliminary study was repeated in the main study. The resultant photographic file of the study mark views of the four sites on each breast consisted of 72 black and white prints for each of the 20 subjects.

4.3.3. Assessment of ptosis

The subjects' data of age, bust size and cup size consisted of known values. The degree of ptosis of the subjects' breasts was assessed by studying the lateral views of each subject (Figure 4.2). The classification of breast morphology described by Rawson and Brooks (1984) as shown in Figure 1.2 was used to create a ptosis index. Adult mature was classified as 1, first degree ptosis as 2, second degree ptosis as 3 and third degree ptosis as 4. The ptosis index values for each subject were verified independently by an experienced forensic dentist.

4.3.4. Digitising of photographic prints

The data recording equipment comprised a Western 286 turbo computer, a Samsung CM 4531 EGA monitor and an EPSON LX-86 printer. The measurements were recorded by the author using a digital analyser in conjunction with a Summagraphics bitpad and cursor. The assembled data recording equipment is illustrated in Figure 4.3. The measurement sequence for each photographic print was conducted with normal artificial background illumination. Additional spotlight illumination proved inappropriate because of reflected glare from the gloss surface of the photographic prints. To prevent movement, each photographic print was taped to the bitpad. In order to achieve a high level of standardisation and consistency in digitising, the cursor was placed on the print in the same axis each time. The cursor was fitted with red perpendicular cross-wires which contrasted with the black and white prints. The selected measurement points were digitised by superimposing the cursor cross-wires on the selected point and pressing the cursor button. The selected measurement points of the left and right breasts are shown in Figures 4.4 and 4.5 respectively, being in effect mirror images. The digital analyser had been programmed to record 24 measurements in millimetres between the 20 selected points. Clearly, each measurement value required two digitised points. The measurement record was arranged into horizontal, vertical, diagonal and gap values as shown in Table 4.1.

4.3.5 Consistency of digitising

The quality of the study marks varied slightly. Consequently an increased level of subjective judgment was required to record the less well-defined measurement points. In order to assess consistency in digitising the selected measurement points, several photographic prints were digitised on a trial basis. The initial results produced measurement values which differed by a maximum of 1.07mm. With practise, this was reduced to 0.44mm.

The consistency in digitising the selected measurement points was tested by digitising two photographic prints six times. The measurement values were subjected to cumulative comparative analysis. The data were expressed as cumulative means to determine how often a photographic print required to be digitised in order to provide consistent measurement values.

4.3.6 Data collection

The selected measurement points on each photographic print were digitised three times. This was repeated for the three prints of the eight breast sites of each subject. The digital analyser and computer were programmed to produce the resultant measurement values in nine columns as shown in Table 4.2. This enabled consistency in digitising each photographic print to be checked visually at the time of digitising. The initial data for each subject, therefore, consisted of 24 tables; consequently the complete study of the 20 subjects comprised 480 tables of measurement values.

The photographic file for each subject consisted of 72 prints. The 20 selected measurement points on each print were digitised three times. Therefore, the digitised points for each subject totalled 4,320 which resulted in 5,184 measurement values. The individual subject totals became 86,400 digitised points and 103,680 measurement values for the main study of the 20 subjects. In view of the volume of the initial data and the comparative nature of the research, the functioning of the examiner and the data recording equipment were examined.

4.3.7 Functioning of examiner and data recording equipment

The functioning of the examiner was studied in relation to consistency and fatigue. A variety of attempts were made to discover which technique would produce high consistency and minimal fatigue in digitising throughout the study. The measurement points on each photographic print were digitised three times which resulted in three sets of measurement values for comparative purposes. Consistency and fatigue were verified in this way; if the measurement values were comparable then consistency in digitising was high and examiner fatigue was minimal. It was concluded that digitising a maximum of 36 photographic prints in a day was the most appropriate approach. The digitising was conducted during a continuous nine month period to maintain consistency of technique.

The functioning of the data recording equipment was studied to verify consistency. This was undertaken by re-digitising a random sample of 20 prints. The first 20 numbers below 72 were selected from random sampling tables (Hill, 1967) as shown in Table 4.3. The random number for each subject corresponded to the photographic print of the same number. The 20 photographic prints therefore represented a random selection of the 1,440 prints of the main study. Each print was digitised three times in exactly the same manner as described previously. The resultant measurement values were compared with the values of the same print in the main study.

4.3.8. Creation of measurement tables

The horizontal, vertical and diagonal values were much greater than the gap values. A difference in measurement value of 0.44 mm was relatively unimportant to the horizontal, vertical and diagonal values when subjected to cumulative comparative analysis; however, 0.44 mm was important to the gap values. In effect, minor inconsistencies in recording the selected measurement points produced disparity when the horizontal, vertical and diagonal values were contrasted with the gap values when cumulative comparative analysis was conducted. Therefore, it was concluded that the horizontal, vertical and diagonal values should be studied separately from the gap values.

The measurement value data was reorganised using WordStar 3.0. This simple word processing package was used as it produced tables which could be read directly into the statistical package Minitab. The horizontal, vertical and diagonal values which comprised the first 16 rows of each measurement value table, were blocked to another file. The resultant measurement data consisted of nine columns of 16 rows for each of the 24 anatomical sites of each subject. The 480 files of measurement values were transferred into Minitab.

The three values for the repeat measurements of each photographic print were averaged. The posture distortion percentage values were calculated in exactly the same manner as described in the preliminary study. The difference between the measurement value photographed with the arm in the position in which the study mark was made and the corresponding value photographed with the arm in each of the other two positions studied was expressed as a percentage change from the first measurement value. The relationship of the posture distortion percentage values to the photographic sequence of the left and right breasts is demonstrated in Tables 4.4 and 4.5 respectively.

In view of the large volume of data, it was considered appropriate to concentrate initially on certain measurements from the left breast for study. The longest measurements in each axis reflected the major dimensions encountered in bite mark cases. Consequently, the upper and lower horizontal, the medial and lateral vertical and the upper medial to lower lateral and upper lateral to lower medial diagonal measurements were studied. The relationship between the measurements, axes and body planes are demonstrated in Figure 4.6.

The posture distortion percentage values for the 20 subjects were cast into a separate measurement table for each of the six selected measurements. Addition of the subjects' data for age, bust size, cup size and ptosis index produced 28 columns as shown in Tables 4.6 to 4.11. The posture distortion percentage values consisted of negative and positive values. Posture distortion occurred as expansion and contraction which were expressed as negative and positive values respectively.

After the creation of the measurement tables, the posture distortion percentage values were checked to confirm that all values had transferred accurately from the initial data. Minor errors were detected in two instances and these were corrected.

4.3.9. Analysis of measurement tables

The analysis of the measurement tables in the initial stages of the main study was conducted in order to provide an overview of posture distortion. The maximum expansion and contraction values of each of the six measurements were noted. In addition, the parameters of age, bust size, cup size and ptosis were assessed to determine if there was significant correlation between them. Correlation coefficient values were assessed using linear correlation tests within Minitab. Utilising Pearson's correlation coefficient (Altman, 1991) for a sample size of 20, a correlation of > + 0.4438 or < - 0.4438 is significant at the 5% level. Where correlation coefficients were assessed as statistically significant the data were plotted as graphs.

The analysis of the measurement tables focused on the four arm movements which were considered to be the most relevant to bite mark cases. The arm movements selected were horizontal to up, horizontal to down, up to down and down to up.

4.4. RESULTS

4.4.1 Subjects

The age, bust size, cup size and ptosis index of the 20 subjects are shown in Table 4.12.

The initial frontal photographs demonstrated dimensional changes in breast morphology produced by the different arm positions as illustrated in Figure 4.1. The degree of dimensional change was related to the extent of arm movement.

A number of subjects in the main study showed greater dimensional change than was evident in the preliminary study. This is demonstrated when Figures 4.7a, 4.7b and 4.7c are compared with Figures 3.7a, 3.7b and 3.7c.

4.4.2 Consistency of digitising

The repeat measurement values and the cumulative comparative analysis data are shown in Table 4.13. The cumulative comparative mean values demonstrated that there was virtually no improvement in the consistency of the values for the large measurements after the third time. However, the gap measurements, the last eight rows in Table 4.13, showed a lack of consistency in the values after the third time. The photographic prints of the 20 subjects were digitised three times for the study of the large measurements reported in this Chapter..

4.4.3 Functioning of data recording equipment

The measurement values of one of the 20 photographic prints from the main and random studies are shown in Table 4.14. Random statistical analysis demonstrated that the measurement values of the main study compared favourably with the values of the random study for each subject. Therefore, the functioning of the data recording equipment was consistent during the initial stages of the main study.

4.4.4 Analysis of measurement tables

Examination of the posture distortion percentage values of the 20 subjects identified the maximum expansion and contraction values for each of the six measurements. The maximum posture distortion percentage values are shown diagrammatically in Figure 4.8.

The maximum expansion values were higher than the maximum contraction values for each of the horizontal measurements. The upper and lower horizontal measurements demonstrated comparable maximum expansion and maximum contraction values.

The maximum expansion and contraction values were comparable for each of the vertical measurements. However, the lateral vertical measurement demonstrated higher maximum expansion and contraction values than the medial vertical measurement.

The maximum expansion and contraction values were comparable for the upper medial to lower lateral diagonal measurement. The maximum expansion value was higher than the maximum contraction value for the upper lateral to lower medial diagonal measurement. The upper medial to lower lateral diagonal measurement demonstrated higher maximum expansion and contraction values than the upper lateral to lower medial diagonal measurement.

Maximum expansion occurred in the upper and lower horizontal measurements. Maximum contraction occurred in the upper and lower horizontal , lateral vertical and upper medial to lower lateral diagonal measurements.

Further examination of the maximum expansion and contraction percentage values for each of the six measurements identified the relevant arm movement, breast site and subject. The data is shown in Table 4.15.

The maximum expansion and contraction values were produced almost exclusively by the most extensive arm movements and these were found in the outer, upper and nipple sites. The maximum expansion and contraction values were mainly related to older subjects with larger cup size and increased ptosis index.

The correlation coefficients of the age, bust size, cup size and ptosis index are shown in Table 4.16. The only statistically significant correlation appeared to be age with ptosis. The measurement of ptosis was on an ordinal scale, but it is unlikely that with a sample of 20 subjects this would adversely affect the linear correlation. When a Spearman rank correlation coefficient, with correction for ties was undertaken, this confirmed the significant positive correlation of age with ptosis ($P< 0.002$). Age, bust size and cup size were not significantly correlated with each other. Bust size, cup size and ptosis index were not significantly correlated with each other. The subjects' age appeared significantly correlated with the ptosis index. The nature of the significance of age and ptosis was demonstrated by plotting the statistically significant correlation coefficient of the subjects' age and the ptosis index as a graph (Figure 4.9). Age and ptosis were found to be positively correlated. An increase in the subjects' age was related to an increase in the ptosis index.

4.5 DISCUSSION

The creation and photography of the study marks were conducted in exactly the same manner as described in the preliminary study. The unavoidable subjective components of variable tissue deformation during mark creation and variations in film to mark distance and film to mark parallelism during photography were minimised by prior recognition and subsequent care and attention. As in the preliminary study, the subjective component was not considered to be a relevant factor in the initial stages of the main study.

The subjects' data of age, bust size and cup size consisted of known values. The creation of a ptosis index involved a minor element of subjective judgment in assessing the lateral photographic views of each subject. The subjective element was minimised by independent corroboration of the ptosis index by an experienced forensic dentist.

The subjective component of data collection related to the increased level of subjective judgment required to record the less well-defined measurement points. Cumulative comparative analysis demonstrated that there was virtually no improvement in the consistency of the large measurement values after the third time. Data collection was conducted three times which permitted consistency of digitising to be checked visually and produced an average value for analysis. Random statistical analysis demonstrated that the functioning of the data recording equipment was consistent during data collection.

The creation and photography of the study marks and the data collection were conducted with precision in order to maximise standardisation and consistency in view of the comparative nature of the subsequent data analysis.

The initial stages of the main study established a protocol for the creation and photography of study marks, data collection and selection of data for analysis.

In view of the volume of the data and the extent of the analysis, the horizontal, vertical and diagonal measurement tables were analysed separately and reported accordingly in Chapters 5, 6 and 7 respectively.

4.6 CONCLUSIONS

The magnitude of posture distortion was very variable. Maximum expansion occurred in the upper and lower horizontal axes. Maximum contraction occurred in the upper and lower horizontal, lateral vertical and upper medial to lower lateral diagonal axes. Maximum posture distortion was produced almost exclusively by the most extensive arm movements and occurred in the outer, upper and nipple sites.

Maximum posture distortion was mainly related to older subjects with a larger cup size and an increased ptosis index. An increase in the subjects age was related to an increase in the ptosis index.

The initial stages of the main study produced general conclusions which would require more detailed analysis.

1. Arms vertically down

2. Arms horizontal

3. Arms vertically up

Figure 4.1 The three frontal views of a subject

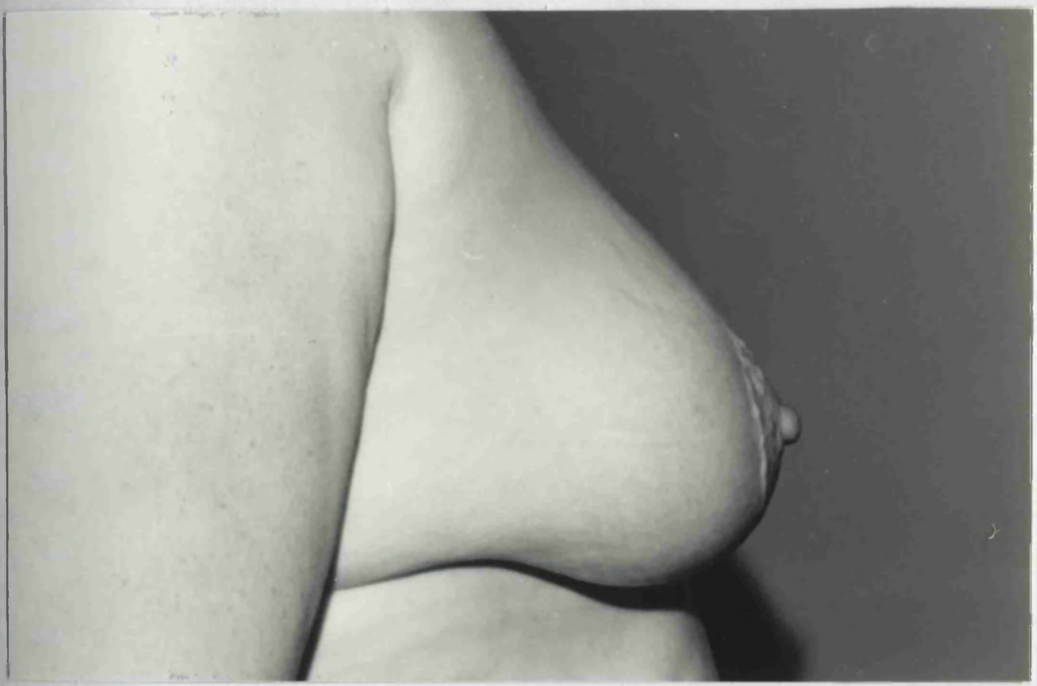


Figure 4.2 The lateral view of a subject

Figure 4.3 **The data recording equipment**

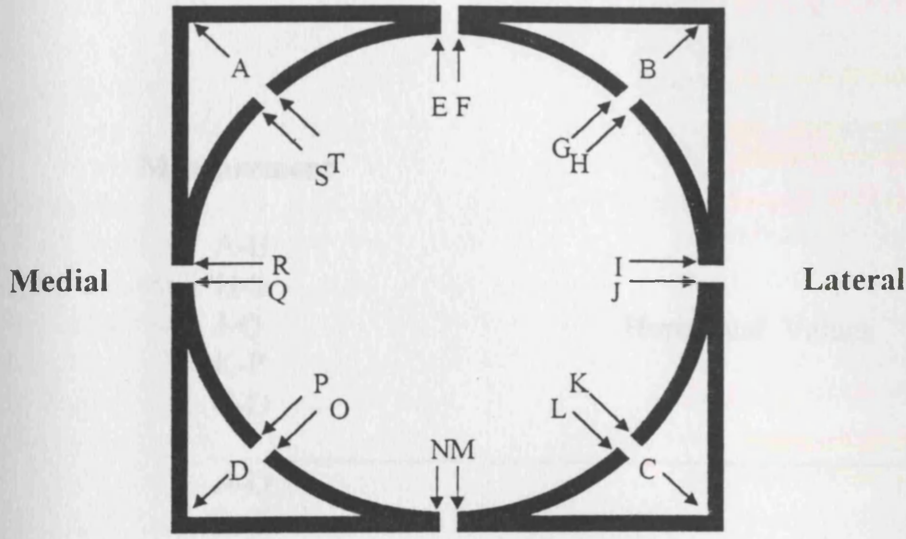


Figure 4.4 **Diagram of the measurement points of the left breast**

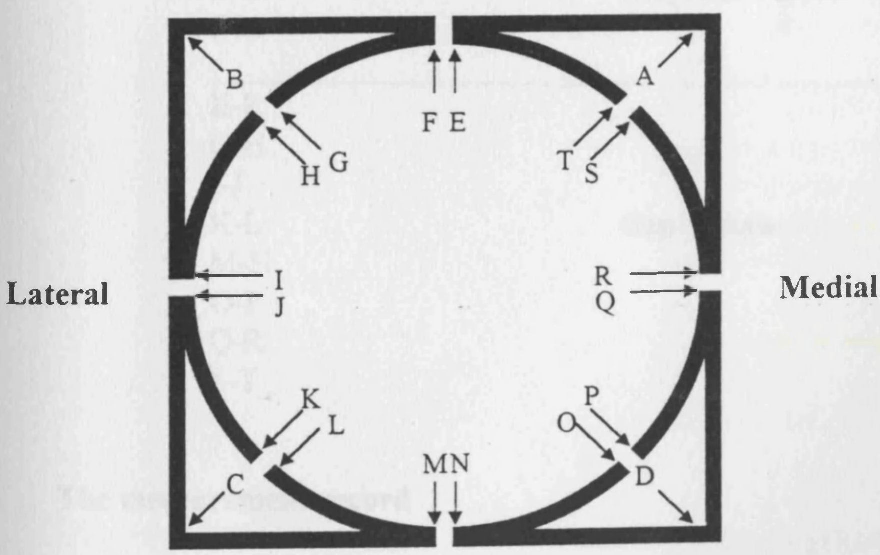


Figure 4.5 **Diagram of the measurement points of the right breast**

Measurement	
A-B H-S J-Q K-P C-D	Horizontal Values
A-D O-T E-N G-L B-C	Vertical Values
F-I A-C N-Q	Diagonal Values
E-R B-D J-M	Diagonal Values
E-F G-H I-J K-L M-N O-P Q-R S-T	Gap Values

Table 4.1 The measurement record

	Print 1			Print 2			Print 3		
Measurement	1	2	3	1	2	3	1	2	3
A-B									
H-S									
J-Q									
K-P									
C-D									
A-D									
O-T									
E-N									
G-L									
B-C									
F-I									
A-C									
N-Q									
E-R									
B-D									
J-M									
E-F									
G-H									
I-J									
K-L									
M-N									
O-P									
Q-R									
S-T									

Table 4.2 The repeat measurement records of the three photographic prints of a single breast site in each of the three arm positions

Subject	Random Number
A	6
B	34
C	34
D	47
E	22
F	23
G	20
H	65
I	39
J	72
K	19
L	72
M	69
N	62
O	7
P	36
Q	49
R	14
S	21
T	70

Table 4.3 Random sampling numbers for the 20 individuals

	Site	Mark Made (arm)	Photo(arm)	Posture Distortion
1	outer	down	down	DD-DH
	outer	down	horizontal	
	outer	down	up	DD-DU
2	outer	horizontal	horizontal	HH-HU
	outer	horizontal	up	
	outer	horizontal	down	HH-HD
3	outer	up	up	UU-UD
	outer	up	down	
	outer	up	horizontal	UU-UH
4	upper	down	down	DD-DH
	upper	down	horizontal	
	upper	down	up	DD-DU
5	upper	horizontal	horizontal	HH-HU
	upper	horizontal	up	
	upper	horizontal	down	HH-HD
6	upper	up	up	UU-UD
	upper	up	down	
	upper	up	horizontal	UU-UH
7	inner	down	down	DD-DH
	inner	down	horizontal	
	inner	down	up	DD-DU
8	inner	horizontal	horizontal	HH-HU
	inner	horizontal	up	
	inner	horizontal	down	HH-HD
9	inner	up	up	UU-UD
	inner	up	down	
	inner	up	horizontal	UU-UH
10	nipple	down	down	DD-DH
	nipple	down	horizontal	
	nipple	down	up	DD-DU
11	nipple	horizontal	horizontal	HH-HU
	nipple	horizontal	up	
	nipple	horizontal	down	HH-HD
12	nipple	up	up	UU-UD
	nipple	up	down	
	nipple	up	horizontal	UU-UH

Table 4.4 The photographic sequence of the left breast

	Site	Mark Made (arm)	Photo(arm)	Posture Distortion
13	outer	down	down	DD-DH
	outer	down	horizontal	
	outer	down	up	DD-DU
14	outer	horizontal	horizontal	HH-HU
	outer	horizontal	up	
	outer	horizontal	down	HH-HD
15	outer	up	up	UU-UD
	outer	up	down	
	outer	up	horizontal	UU-UH
16	upper	down	down	DD-DH
	upper	down	horizontal	
	upper	down	up	DD-DU
17	upper	horizontal	horizontal	HH-HU
	upper	horizontal	up	
	upper	horizontal	down	HH-HD
18	upper	up	up	UU-UD
	upper	up	down	
	upper	up	horizontal	UU-UH
19	inner	down	down	DD-DH
	inner	down	horizontal	
	inner	down	up	DD-DU
20	inner	horizontal	horizontal	HH-HU
	inner	horizontal	up	
	inner	horizontal	down	HH-HD
21	inner	up	up	UU-UD
	inner	up	down	
	inner	up	horizontal	UU-UH
22	nipple	down	down	DD-DH
	nipple	down	horizontal	
	nipple	down	up	DD-DU
23	nipple	horizontal	horizontal	HH-HU
	nipple	horizontal	up	
	nipple	horizontal	down	HH-HD
24	nipple	up	up	UU-UD
	nipple	up	down	
	nipple	up	horizontal	UU-UH

Table 4.5 The photographic sequence of the right breast

Selected Measurement	Original Measurement	Axis	Body Plane	
1	A-B		Upper	
	H-S		↓	
	J-Q	Horizontal Values		
	K-P			
5	C-D		Lower	
6	A-D		Medial	
	O-T		↓	
	E-N	Vertical Values		
	G-L			
10	B-C		Lateral	
	F-I		Medial	Upper
12	A-C	Diagonal Values	↓	↓
	N-Q		Lateral	Lower
	E-R		Lateral	Upper
15	B-D	Diagonal Values	↓	↓
	J-M		Medial	Lower

Figure 4.6 The measurements, axes and body planes

		C1	C2	C3	C4	Outer C5	C6	C7	Upper C8	C9	C10	Inner C11	C12	C13	Nipple C14	C15
		Age	Bust	Cup	DD-DH	HH-HU	UU-UD	DD-DH	HH-HU	UU-UD	DD-DH	HH-HU	UU-UD	DD-DH	HH-HU	UU-UD
	1	50	32	1	10.8823	2.6929	-15.9572	8.1078	2.0618	-11.0684	4.8166	0.0432	-4.2427	5.4136	4.1616	-10.7179
	2	42	36	1	4.2181	13.6049	-20.5782	1.1564	8.9526	-17.7195	4.1046	4.7484	-11.0198	8.8356	6.2680	-28.6564
	3	29	36	2	5.9094	6.6826	-9.2241	4.5900	5.5116	-10.9210	1.6653	2.0864	-2.0228	5.2412	9.9588	-16.4436
	4	58	40	3	6.7275	8.8378	-12.4852	8.8000	11.0140	-33.2329	6.2436	3.9527	-7.0086	14.8472	13.7814	-31.5474
	5	20	34	1	0.9872	4.1126	-11.9321	3.0914	7.9442	-18.6298	6.4305	3.8884	-7.7473	6.2446	6.6375	-12.8238
	6	20	34	2	6.0210	5.2525	-12.2615	-0.3317	2.6806	-2.3150	4.5641	3.6980	-7.2251	6.4909	4.9388	-8.1230
S	7	30	36	5	9.0399	12.6807	-15.8545	2.5258	2.8485	-14.0349	5.5985	-10.2929	5.6194	13.5492	4.7917	-22.7964
U	8	29	36	1	14.3950	10.7681	-16.0677	0.4268	9.4132	-19.5590	3.3470	4.4180	-10.0829	4.2227	3.6011	-8.9822
B	9	46	38	3	8.2309	6.2447	-20.2252	8.9288	1.5119	-25.7568	7.1906	7.6805	-11.3386	13.8284	7.3147	-19.4655
J	10	35	36	2	8.1622	4.5440	-12.1416	2.7990	2.0890	-13.1441	-1.4827	4.8636	-7.6365	10.6360	9.8775	-21.8729
E	11	32	38	2	5.4797	4.9108	-10.6067	3.9364	-0.1374	-5.7288	1.3430	2.1883	-3.2418	8.1361	-0.8158	-32.2294
C	12	39	34	3	5.8263	6.7073	-22.5550	0.8790	4.5055	-19.3519	3.5460	4.5142	-13.0319	9.0770	-0.1536	-26.0336
T	13	39	36	1	7.9967	6.7581	-14.6057	3.7952	4.2607	-15.5449	1.0654	4.4057	-6.5078	2.4331	1.4343	-14.6141
	14	27	36	2	10.6665	4.4332	-14.9527	4.4620	-4.2560	-10.3098	1.6525	3.3364	-10.3102	7.9889	4.8788	-15.6448
	15	64	38	3	10.1026	8.8792	-14.8366	-5.2930	1.2629	-29.3482	4.0712	0.2344	-9.3607	6.2704	4.4864	-36.3536
	16	58	34	2	7.0040	11.4561	-22.1997	4.4017	4.6517	-27.4003	2.7637	5.4720	-15.5390	16.4813	8.8717	-34.0134
	17	53	34	3	4.2794	6.3000	-17.4318	4.5599	-12.3686	-29.9338	-3.7294	2.0893	-11.4904	13.1099	8.4507	-37.2116
	18	45	34	3	6.9934	7.7042	-8.6524	3.4023	1.3132	-16.5741	0.1865	2.9206	-5.0275	10.4910	7.2767	-30.2535
	19	54	36	2	11.3615	12.9858	-27.7796	9.2994	6.1194	-22.7922	7.1788	7.9125	-20.4935	11.9495	5.9849	-23.1995
	20	43	34	3	12.1620	9.4184	-12.5740	-4.3826	2.7444	-12.4553	1.8534	0.8814	-5.2282	8.3219	-0.1599	-20.0452

C16	Outer C17	C18	C19	Upper C20	C21	C22	Inner C23	C24	C25	Nipple C26	C27	C28
DD-DU	HH-HD	UU-UH	DD-DU	HH-HD	UU-UH	DD-DU	HH-HD	UU-UH	DD-DU	HH-HD	UU-UH	Ptosis
11.8864	-16.3434	4.7090	7.2330	-5.5325	-1.6540	4.4197	-3.6046	-0.0844	5.7185	-5.2296	-4.0206	3
14.8898	-9.2109	-8.8694	11.1394	-3.4005	-9.7943	5.3964	-1.3627	-6.4828	14.2058	-23.3666	-13.4692	3
12.3408	-4.0469	-2.8895	8.7311	-3.8550	-4.3131	2.6169	0.6989	-1.8893	13.4266	-1.9202	-10.5126	3
16.9815	-6.0136	-6.5634	20.6800	-12.4771	-19.1417	13.2536	-3.4943	-2.9692	27.5328	-11.2327	-13.7573	4
6.0217	-8.0195	-1.9487	6.3363	-7.6848	-8.2019	5.4428	-2.7359	-1.9645	7.8461	-6.3746	-5.2558	1
11.0439	-6.5789	-6.7459	-0.0535	-4.8293	-1.4588	8.6285	-2.6736	-2.5318	11.8488	-2.1525	1.1327	2
17.6122	-5.4946	-6.6862	4.0706	-9.7078	-5.1232	11.9394	-2.8990	-4.1696	19.6432	-12.1442	-10.8117	2
14.3886	-2.6098	-5.4078	7.0964	-4.7700	-9.9925	6.2312	-1.2843	-1.8361	10.0098	-4.8864	-3.6923	1
11.6147	-11.2784	-11.4510	14.3655	-14.8510	-10.9771	7.9107	-2.8956	-6.3878	20.8920	-6.5788	-8.1737	3
14.7632	-6.3176	-6.8212	5.7013	-4.7982	-7.9912	2.5736	-2.6133	-6.7688	19.4320	-6.2350	-14.8193	2
9.8429	-4.4596	-3.8279	4.0190	-7.5777	-2.2753	2.1404	-1.5676	-0.7664	6.4923	-23.6360	-25.3053	2
14.9703	-11.4407	-11.3834	5.3445	-6.5620	-10.0823	5.0855	-4.3090	-3.6927	14.6637	-21.4191	-15.1809	3
13.4843	-13.1599	-10.7762	8.5892	-7.5040	-11.8235	5.0971	-0.1974	-2.2928	5.5825	-15.2115	-7.8894	3
13.9461	-6.0406	-4.2327	-1.5558	-9.1609	-1.2073	1.9140	-4.7413	-3.7814	11.5988	-6.9342	-5.0423	2
18.8086	-3.1583	-9.3997	-7.0889	-3.6446	-15.7877	1.9538	-5.4825	-3.9046	8.6612	-5.9354	-16.4923	3
18.0603	-8.9497	-10.0852	5.9626	12.5701	-10.5296	4.6579	-3.7201	-8.7628	22.8074	-21.8596	-15.1146	4
9.8478	-8.1826	-10.7630	12.1845	-14.5908	-16.2526	-0.2877	-1.6545	-9.9221	19.7497	-15.7530	-13.7680	3
17.1522	-4.1365	-3.3866	3.4130	-7.4452	-5.7727	4.1127	-2.8128	-0.1451	15.0757	-19.8911	-14.3097	3
25.4650	-11.0220	-11.4191	14.6571	-10.7036	-6.9381	14.9130	-6.6343	-8.3909	21.3525	-13.5132	-11.5360	4
17.1562	-4.8535	-3.1171	1.0064	1.0506	-9.2889	1.4167	-0.8495	-2.0014	10.4682	-16.4357	-8.0565	3

Table 4.6 The measurement table for measurement 1, the upper horizontal of the study mark. The values in C4-C27 are the posture distortion percentage values.

Subject	C1 Age	C2 Bust	C3 Cup	C4 DD-DH	Outer C5 HH-HU	C6 UU-UD	C7 DD-DH	Upper C8 HH-HU	C9 UU-UD	C10 DD-DH	Inner C11 HH-HU	C12 UU-UD	C13 DD-DH	Nipple C14 HH-HU	C15 UU-UD
1	50	32	1	10.0061	11.7505	-25.3400	6.0456	2.3685	-14.6522	3.1509	7.5776	-5.0020	7.2872	7.1921	-13.1061
2	42	36	1	5.9888	17.2554	-22.5146	2.7578	4.1165	-27.6217	6.5320	8.1087	-16.8747	11.6219	9.2869	-32.8039
3	29	36	2	4.1291	4.7766	-8.3546	7.6595	9.0627	-16.7527	0.9793	3.1011	-0.3000	6.6173	11.1762	-13.0274
4	58	40	3	3.7242	5.9227	-8.1151	9.3004	9.6438	-36.5636	2.0073	3.7640	-3.4042	11.7721	12.3991	-24.3529
5	20	34	1	6.6737	7.8578	-16.0787	1.8226	4.9383	-12.9481	4.3125	3.4852	-6.9261	3.8576	6.7243	-11.5339
6	20	34	2	9.8449	9.4190	-14.9246	5.7404	8.8107	-5.4914	7.0483	6.7552	-9.5597	7.3363	8.4103	-7.2087
S 7	30	36	5	5.2605	10.8909	-12.4478	9.0891	4.2191	-20.7997	3.6275	-12.0282	4.8472	12.5889	6.1059	-20.7692
U 8	29	36	1	9.8352	11.4535	-21.8576	-0.4851	-4.2821	-14.5676	3.8586	1.0528	-6.9897	4.9201	5.0147	-7.9050
B 9	46	38	3	4.7845	6.4483	-12.7748	13.1300	0.0000	-24.1383	4.5098	6.3110	-9.4949	12.9178	8.3036	-16.7539
J 10	35	36	2	7.2075	5.3762	-11.9431	11.1470	7.6287	-25.6996	0.5086	3.0831	-4.0311	11.8351	9.5404	-16.7164
E 11	32	38	2	3.6752	3.5221	-6.6687	2.4522	2.0443	-14.1242	2.0607	2.6974	-4.9446	5.8629	0.5667	-19.9979
C 12	39	34	3	5.5725	8.6165	-21.2964	6.8292	3.2548	-24.2124	6.5748	5.4090	-10.3142	7.1881	2.8332	-20.3754
T 13	39	36	1	13.4122	10.6094	-25.0381	2.9171	2.5426	-15.6026	5.9112	5.2714	-12.4900	5.6285	4.6725	-15.6684
14	27	36	2	9.7265	6.2917	-15.8670	9.8599	0.8033	-13.8604	2.4307	3.6328	-10.7781	6.2588	5.7830	-12.7935
15	64	38	3	4.4264	6.7733	-15.0259	-1.0533	6.8096	-38.6720	3.9367	3.6939	-8.3992	6.5015	7.4976	-37.9534
16	58	34	2	1.8677	13.0501	-13.8055	11.2354	7.2069	-32.2570	0.4541	5.7681	-10.6780	15.0098	8.9942	-30.2288
17	53	34	3	2.4210	6.7761	-12.2775	10.4487	9.1283	-36.9777	-0.7165	4.3501	-7.9239	12.4438	8.6891	-24.3590
18	45	34	3	5.0546	7.4148	-4.9042	9.4312	4.6139	-32.0477	-0.8885	1.7840	-2.6319	7.7128	10.0941	-19.1833
19	54	36	2	7.3264	13.0198	-26.6623	8.9583	5.2086	-25.8218	3.4716	6.7465	-13.6037	9.3780	8.2660	-20.5555
20	43	34	3	13.5847	13.7405	-21.8773	0.5254	0.0000	-17.2277	4.1500	4.1035	-8.7953	6.4327	2.3969	-18.1858

C16 DD-DU	Outer C17 HH-HD	C18 UU-UH	C19 DD-DU	Upper C20 HH-HD	C21 UU-UH	C22 DD-DU	Inner C23 HH-HD	C24 UU-UH	C25 DD-DU	Nipple C26 HH-HD	C27 UU-UH	C28 Ptosis
23.4457	-9.2498	-6.0578	6.4810	-8.5207	-3.1807	7.2969	-1.5115	-1.2810	12.3562	-9.1824	-2.4083	3
20.5552	-4.9865	-12.8508	11.8897	-11.9032	-11.7843	11.7350	-1.6504	-11.5637	21.2018	-19.8765	-16.7470	3
11.5182	-1.5100	-4.4476	12.8098	-6.0668	-5.4659	2.5094	1.8158	-0.4448	13.4850	-0.0650	-9.4572	3
16.5450	-2.6032	-4.4807	19.6264	-16.3449	-20.6755	8.1038	0.6118	-1.7218	22.2491	-8.5823	-11.0736	4
15.4040	-6.5078	-6.8165	7.5116	-5.7864	-5.1792	4.3937	-5.2593	-1.2361	6.8734	-4.0521	-5.2967	1
19.6695	-7.3382	-7.9665	12.0336	-0.9045	-1.7608	14.1869	-1.2398	-4.2795	14.9139	-0.0217	2.8184	2
15.7507	-3.5860	-6.1476	12.0305	-14.6998	-9.3772	11.1866	-6.1314	-5.5556	17.3761	-9.9495	-8.6870	2
17.7566	-6.5734	-6.3275	3.0653	-17.7461	-11.2998	2.8560	-2.7637	-0.4556	9.3566	-3.1724	-2.3967	1
9.6638	-6.7358	-7.6124	21.0080	-19.7419	-10.8358	8.1420	-3.5729	-5.6373	21.6658	-4.7897	-8.1043	3
15.6145	-3.2566	-7.1392	15.1199	-7.6403	-14.4392	2.9891	-1.2291	-3.6683	20.3336	-4.6970	-11.2217	2
9.5062	-3.6883	-2.1000	4.3924	-13.3576	-8.1474	4.4597	-3.3310	-2.6183	5.3760	-18.1551	-17.4315	2
19.1479	-9.4964	-12.9336	11.2400	-17.5196	-11.1249	9.6444	-5.1350	-4.0299	14.7387	-20.1902	-11.1474	3
24.4991	-14.4873	-13.3415	6.3825	-10.3359	-10.1085	10.5972	-7.3237	-2.7622	11.5929	-12.2549	-5.2360	2
17.8061	-3.8438	-2.9894	10.2834	-9.9703	-1.6432	3.8226	-4.1606	-2.8019	11.5400	-4.6011	-4.9214	3
16.3216	-2.1532	-5.3294	-0.5818	-9.2543	-17.6042	4.5123	-4.6149	-1.6312	12.9102	-11.5495	-15.8419	4
14.1457	-3.1130	-8.1596	14.6009	-21.5680	-13.8230	6.1692	-1.8119	-7.9311	23.1521	-14.4675	-15.9724	3
12.6265	-5.1860	-9.3959	15.1603	-19.5575	-18.0502	3.0477	-2.2381	-7.1018	19.5852	-8.7105	-10.1504	3
15.7982	-2.2507	-0.6384	13.1322	-20.2927	-13.9658	4.5958	-1.3274	-1.2905	11.6714	-12.9265	-10.8377	4
19.4301	-8.4684	-12.8987	16.4271	-16.5679	-11.1013	11.6555	-3.5414	-7.2907	20.4610	-8.4024	-11.2477	3
24.2942	-2.3654	-12.3053	3.9099	-8.9782	-10.7902	4.9083	-1.2063	-4.3219	9.7262	-15.2338	-5.2603	3

Table 4.7 The measurement table for measurement 5, the lower horizontal of the study mark. The values in C4-C27 are the posture distortion percentage values.

Subject	C1 Age	C2 Bust	C3 Cup	C4 DD-DH	Outer C5 HH-HU	C6 UU-UD	C7 DD-DH	Upper C8 HH-HU	C9 UU-UD	C10 DD-DH	Inner C11 HH-HU	C12 UU-UD	C13 DD-DH	Nipple C14 HH-HU	C15 UU-UD
1	50	32	1	-2.13890	-9.13290	6.71240	-2.89825	-4.07700	7.4959	-2.01692	-5.35900	8.1827	-5.4975	-2.50131	7.6471
2	42	36	1	0.35100	-6.23300	9.36720	-8.30350	-4.46760	11.9419	-5.14060	-0.52010	4.2327	-1.2625	-1.89280	10.0975
3	29	36	2	-1.43641	3.77641	-2.97526	-2.80402	-1.04187	2.3970	-0.26436	0.75593	-1.4712	3.8240	7.53380	-6.1776
4	58	40	3	-1.56191	0.03078	0.85190	-1.39002	-2.08670	8.8711	-2.49217	-0.81761	2.1873	1.2448	0.91460	-0.2574
5	20	34	1	-3.32760	-5.30440	8.49980	-2.54113	-1.47985	6.6305	-0.98475	-6.01630	5.2948	0.8636	-3.38481	8.7747
6	20	34	2	0.59375	-1.63952	-2.67370	2.09358	-5.57115	6.3905	-0.05332	-7.04878	4.8258	4.5225	1.59820	-1.5985
S 7	30	36	5	-1.32458	0.90990	-4.80590	-1.18859	-3.04428	7.7934	0.82483	-0.53150	-0.7427	4.4739	4.72690	-4.7483
U 8	29	36	1	-4.04820	-4.95000	5.18780	-4.60060	-0.52740	8.6640	-1.20714	-3.81869	4.6990	-2.2944	0.85385	1.8379
B 9	46	38	3	1.37650	1.29759	-2.20320	-2.81900	-2.79255	7.8223	2.93510	-1.84290	4.7564	6.7240	0.22230	2.3597
J 10	35	36	2	-1.72951	0.32338	-6.17570	-1.93460	-1.40187	4.8798	-0.45753	-2.44748	-0.6982	6.2788	3.09980	-1.8199
E 11	32	38	2	0.32464	-0.12591	-3.51570	-3.5556	1.28859	4.8836	-3.54155	0.76108	4.5183	1.7719	-3.35242	-7.8879
C 12	39	34	3	1.41240	-1.29476	-1.19790	1.73822	1.09557	6.5115	-0.58229	-1.99253	2.3070	1.7808	-0.84375	-2.5700
T 13	39	36	1	-0.84210	-8.13780	7.21440	-8.85600	0.53920	11.1974	-3.41110	-4.04300	6.7788	-10.9814	-5.40290	9.8422
14	27	36	2	-2.48740	0.19887	1.61550	-0.06359	-1.70250	5.6008	-0.70584	-5.16833	8.4621	1.3827	1.11133	1.7349
15	64	38	3	-1.92570	1.61650	-4.09700	-1.81890	2.37870	13.1183	7.26200	4.18410	-10.5036	7.8539	7.94360	-0.7533
16	58	34	2	1.41049	-1.62060	-4.29870	-3.35320	-0.50170	8.7954	3.64054	-0.48093	3.0131	5.9875	-0.17881	-4.9221
17	53	34	3	1.55620	1.24610	-1.73500	1.30770	-3.06390	9.8078	1.73890	-6.34030	6.7473	9.8340	-2.04770	0.9935
18	45	34	3	-1.37573	-1.72681	1.38660	-0.91002	0.64570	4.9395	-4.20835	-4.62045	4.8237	1.3758	3.30200	-3.1122
19	54	36	2	-5.58350	-4.23220	6.47950	-3.00914	-1.18162	6.9370	1.55537	-5.04762	4.0992	-1.3622	-3.25310	4.0980
20	43	34	3	1.10750	0.39680	-1.80980	-5.61720	-1.92870	10.5638	1.50930	-1.13440	7.0780	5.9797	0.90950	-4.9526

Subject	C16 DD-DU	Outer C17 HH-HD	C18 UU-UH	C19 DD-DU	Upper C20 HH-HD	C21 UU-UH	C22 DD-DU	Inner C23 HH-HD	C24 UU-UH	C25 DD-DU	Nipple C26 HH-HD	C27 UU-UH	C28 Ptosis
1	-4.8179	0.89130	4.17940	-6.4131	5.06430	1.15241	-7.23240	1.0492	3.45178	-9.7319	2.3437	3.93583	3
2	-5.2742	1.66410	6.63550	-13.5532	5.19760	5.69750	-5.75870	4.0108	0.00000	-8.3547	0.7411	6.96480	3
3	0.0698	1.08183	-1.59724	-1.9405	1.02166	0.12086	0.88460	-0.0696	-1.88432	9.9564	0.6766	-5.27670	3
4	-0.8528	-0.05134	-2.22109	-5.5093	3.54130	3.30350	-4.17100	2.9070	1.60331	2.1577	0.1247	-2.02720	4
5	-5.6288	-0.19607	6.99860	-5.6516	3.19060	4.27841	-4.72260	2.5691	3.15112	-1.8872	1.0406	8.34930	1
6	0.0521	-1.65003	-0.80107	-0.5862	-0.50930	4.59632	-5.45010	-1.1801	3.95216	4.6595	0.3069	0.76121	2
7	0.6362	-2.95962	-3.80603	-3.0293	3.81610	3.71118	3.07250	1.1360	-1.97010	5.5766	-3.2450	-1.04700	2
8	-5.7288	1.40510	1.33670	-5.6762	5.13660	4.40690	-4.94610	-0.1514	3.34741	-1.8074	0.8648	0.81801	1
9	2.5064	-1.43700	-2.35290	-2.9242	2.54700	4.07800	-2.33567	1.3487	3.41086	8.0200	-0.7094	3.68835	3
10	-0.7664	-3.69732	-3.20343	-1.9025	1.94180	3.57510	-0.90465	-0.3046	0.21482	9.6753	-2.5584	0.05260	2
11	0.2513	-0.77649	-2.44292	-3.5659	4.14630	2.08853	-3.36602	4.4534	0.42981	-0.0927	-6.6736	-9.13340	2
12	2.1913	-3.19520	-1.27350	0.5897	5.37350	2.13920	1.20540	-0.0519	2.27536	4.6157	-4.4430	-3.01060	3
13	-4.5368	3.28500	2.19520	-7.6341	8.59590	2.99100	-7.17800	2.1373	0.79320	-12.6891	0.5643	2.35110	2
14	-4.6626	2.53297	-0.58455	0.9432	0.86190	-0.82584	-5.95808	2.2032	3.91994	2.8350	1.0709	1.85813	3
15	1.7994	-7.47530	-3.69980	-3.3109	2.64650	6.89410	8.43070	-11.3000	-4.09790	13.3067	-14.8729	1.83240	4
16	1.5764	-0.69889	-2.28010	-7.1693	3.21490	3.85240	3.48100	-5.2185	5.63779	8.7872	-5.2803	0.46830	3
17	10.4607	-1.41940	-1.59580	-1.9201	2.03910	5.44180	0.18520	-1.8891	7.76930	11.0018	-5.6787	3.12090	3
18	-1.6814	0.86857	-1.33565	0.4136	0.15620	2.32630	-8.91112	-0.9241	3.16391	1.1191	-6.8151	-0.42060	4
19	-9.9601	3.85700	4.74750	-7.2918	6.09150	2.30550	-2.35380	-2.2222	3.60133	-3.7792	0.1122	1.96660	3
20	1.6613	-2.69640	-1.92550	-4.8253	4.87910	1.54890	1.56100	-2.5162	4.83900	9.1339	-8.1643	-1.11270	3

Table 4.8 The measurement table for measurement 6, the medial vertical of the study mark. The values in C4-C27 are the posture distortion percentage values.

		C1 Age	C2 Bust	C3 Cup	C4 DD-DH	Outer C5 HH-HU	C6 UU-UD	C7 DD-DH	Upper C8 HH-HU	C9 UU-UD	C10 DD-DH	Inner C11 HH-HU	C12 UU-UD	C13 DD-DH	Nipple C14 HH-HU	C15 UU-UD
	1	50	32	1	-11.3864	-12.8571	24.1404	-7.6263	-2.47110	11.3479	-0.51430	-8.24850	7.53420	-8.2879	-2.37060	9.6263
	2	42	36	1	-4.6371	-12.8164	22.8070	-12.1269	-5.68960	13.3225	-7.75660	-3.45080	-1.14200	-3.1110	-6.03530	6.8589
	3	29	36	2	-5.2605	-3.3354	6.7386	-5.0369	-1.47422	2.8305	1.63183	4.01984	-6.74950	2.6470	4.68170	-1.7958
	4	58	40	3	-4.0307	-3.7109	6.9089	-2.9289	-2.88010	8.0583	0.67282	3.66179	-0.39089	1.3224	1.71800	-0.7050
	5	20	34	1	-10.5309	-10.2206	17.6602	-4.2912	-6.02450	15.6941	1.18460	-2.42840	4.54100	0.2698	-4.99670	9.6812
	6	20	34	2	-6.7037	-9.2316	12.9245	-3.2443	-7.64470	13.6209	4.33410	-0.72860	-1.64270	2.9078	1.89090	-1.5215
S	7	30	36	5	-3.6588	-2.8793	5.9509	-5.7032	-2.50510	6.1488	2.37700	-3.55070	0.30540	1.8941	2.07430	-0.9245
U	8	29	36	1	-10.8725	-14.8999	25.2345	-12.3150	-6.54740	15.5530	-0.61300	0.60150	5.34140	-4.1575	0.29180	4.3934
B	9	46	38	3	-3.1304	-2.6434	3.5471	-3.0803	-0.79023	6.3535	5.99663	1.53850	3.59260	4.9685	-0.93370	1.6112
J	10	35	36	2	-8.0013	-2.3779	7.6243	-5.6077	-1.43970	4.7779	1.18700	1.49480	-4.51110	3.1337	0.00000	-1.8350
E	11	32	38	2	-2.9961	-2.7813	7.7408	-4.8271	0.54826	2.1527	-0.32458	2.74465	-1.11539	1.2447	-1.53767	-8.6975
C	12	39	34	3	-5.0849	-4.4274	10.7275	-1.1373	-1.44270	8.7413	1.21990	-2.06590	-2.33660	1.7152	-3.00060	-0.1879
T	13	39	36	1	-15.1195	-8.7330	19.8775	-17.1892	-3.28640	19.2336	-5.05270	-5.34510	9.75400	-11.9586	-9.36130	8.9394
	14	27	36	2	-8.6731	-5.2186	16.5003	-7.3815	-3.51400	8.5835	2.06350	-1.16330	3.03840	-0.7231	0.47060	4.0417
	15	64	38	3	-4.2857	-4.4435	8.6498	-2.7055	1.90290	6.0515	8.95080	6.72690	-6.02510	0.4193	2.12170	-0.6948
	16	58	34	2	-3.3182	-5.9617	8.9678	-6.3142	-1.16390	9.3582	6.68060	-2.01790	0.61730	2.5795	-0.39590	-3.0453
	17	53	34	3	0.5879	-0.8731	5.0707	0.4080	-0.30850	4.3757	0.70740	-3.06110	1.67570	8.4535	-1.56470	-1.4715
	18	45	34	3	-5.2350	-6.3193	12.9859	-3.2081	0.04150	4.1903	-1.51310	1.27450	-2.19810	0.1251	3.69510	0.7893
	19	54	36	2	-11.0858	-14.5939	23.5264	-7.9674	-3.58000	13.7208	0.13760	-2.45030	3.95490	-4.6077	-6.31270	9.5243
	20	43	34	3	-6.2036	-5.1440	12.7290	-6.8722	-0.87600	8.1666	2.49610	0.87300	3.28920	5.1814	1.02230	-4.3825

C16 DD-DU	Outer C17 HH-HD	C18 UU-UH	C19 DD-DU	Upper C20 HH-HD	C21 UU-UH	C22 DD-DU	Inner C23 HH-HD	C24 UU-UH	C25 DD-DU	Nipple C26 HH-HD	C27 UU-UH	C28 Ptosis
-23.0029	10.4592	9.6292	-13.2999	8.9201	2.28160	-7.4022	-2.2142	4.97950	-14.4781	5.66600	5.75509	3
-16.1657	6.4689	11.2362	-21.5796	8.8099	5.65750	-10.6064	0.6114	-5.17730	-10.9145	0.06120	4.60240	3
-7.1255	3.6689	2.2395	-5.1293	1.0515	-1.76523	5.0382	-2.5111	-6.34937	6.6277	1.94295	-2.97560	3
-7.2452	3.7929	2.6897	-7.9008	3.1784	2.33780	-0.5279	0.6995	-0.67009	1.7107	2.34470	-1.86160	4
-17.8982	7.4086	10.2355	-15.4164	7.4401	8.58590	0.1087	1.2741	4.18080	-5.7192	2.48180	7.89470	1
-12.6347	7.7278	9.7900	-9.9989	4.5092	6.57880	2.3199	-2.0358	-0.26840	4.3926	2.35840	0.13930	2
-5.9574	2.3906	0.8471	-10.6739	3.3294	2.50820	6.5550	0.1691	-4.35930	2.1854	-1.63990	-0.11690	2
-23.6171	11.4544	11.9005	-19.7780	8.0842	6.72370	-0.6026	3.1579	2.74610	-4.5963	3.42550	0.89130	1
-4.0309	1.9956	1.8108	-2.8417	0.0000	3.12500	3.7597	-1.0005	4.08890	6.1438	1.38442	1.29529	3
-10.4944	4.7772	3.0855	-8.0341	2.5915	1.63120	5.5823	-2.5672	-1.88890	6.2782	-1.08530	-4.27790	2
-5.7917	3.3607	1.8293	-5.9379	4.3861	0.98708	-0.0314	-1.0074	-1.61577	0.6578	-5.35600	-6.29890	2
-9.3258	4.3958	4.0650	-2.0555	5.8025	2.07880	-0.5469	-3.7144	0.33070	2.3039	-1.18970	-0.58450	3
-21.3655	13.3403	8.1749	-20.3135	11.9488	6.01120	-11.5782	2.1444	1.65780	-18.0349	1.44500	2.17650	2
-14.9912	6.9856	4.9179	-10.6142	7.5604	1.20960	0.1362	1.6244	1.74840	-1.6772	5.18620	2.68440	3
-10.5437	3.8395	2.1599	-4.6854	1.8926	0.67240	11.7881	-13.9057	-1.75550	3.3648	-3.23450	1.13040	4
-8.6150	5.2459	3.3998	-12.1145	3.4092	2.09450	6.1056	-5.3812	2.43720	2.7795	-1.92620	-1.33910	3
2.4959	1.2518	2.3766	-0.2092	2.1279	1.04930	-3.4929	-4.1216	1.75190	10.0819	-2.25650	0.46190	3
-9.6832	2.7830	5.8003	-3.1769	0.4466	0.91630	1.4602	-3.3495	-1.27260	3.0657	-3.88510	-1.11120	4
-26.6341	11.2870	12.9534	-12.0556	7.1286	4.49400	-2.3600	-2.5255	1.37150	-8.7425	4.40970	3.55230	3
-11.5598	5.5041	6.6785	-6.5712	4.7033	0.59510	3.7546	-4.2461	3.66160	7.8503	-4.26480	-1.93820	3

Table 4.9 **The measurement file for measurement 10, the lateral vertical of the study mark. The values in C4-C27 are the posture distortion percentage values.**

		C1	C2	C3	C4	Outer C5	C6	C7	Upper C8	C9	C10	Inner C11	C12	C13	Nipple C14	C15
		Age	Bust	Cup	DD-DH	HH-HU	UU-UD	DD-DH	HH-HU	UU-UD	DD-DH	HH-HU	UU-UD	DD-DH	HH-HU	UU-UD
	1	50	32	1	4.6024	-1.3112	-9.5402	2.6319	6.9411	-8.8767	6.7468	8.9482	-4.8093	2.5478	6.0753	-8.7655
	2	42	36	1	5.2999	0.2058	-5.6979	-0.5098	5.8155	-12.8999	3.2577	8.5406	-15.0704	3.7607	6.4004	-15.7005
	3	29	36	2	2.3905	5.8726	-8.6758	4.8600	8.1107	-10.6511	1.3046	3.8698	-5.5033	7.1192	12.5713	-14.9755
	4	58	40	3	3.3377	5.8517	-5.8021	6.9314	8.7038	-20.3246	4.2067	5.5379	-3.3768	11.8985	12.8031	-19.5633
	5	20	34	1	2.3088	0.2070	-2.5054	2.8396	8.9631	-11.3702	3.5117	8.4881	-6.6384	4.9232	7.0827	-6.7482
	6	20	34	2	4.6910	1.0193	-8.4800	6.9683	3.4611	-6.8216	6.3633	8.0839	-7.6885	7.4291	6.4626	-8.2157
S	7	30	36	5	4.0813	8.0085	-10.2585	7.5572	5.5268	-12.9704	2.5295	-8.8177	4.5914	11.0974	6.7472	-18.8773
U	8	29	36	1	0.2499	-2.0573	-5.6654	1.3792	5.4487	-7.7275	6.6821	5.7583	-8.1357	3.7752	5.8219	-7.5171
B	9	46	38	3	10.8491	5.0445	-15.8165	8.2846	3.4102	-14.4235	5.1964	6.9895	-6.4821	15.3570	7.3010	-12.7009
J	10	35	36	2	5.9506	4.4117	-14.3788	7.9074	7.8142	-16.9365	1.2882	4.1633	-6.1534	13.2853	9.3813	-17.3859
E	11	32	38	2	2.4403	2.2153	-5.7413	3.6225	3.7793	-9.5452	2.2536	4.1706	-3.5131	6.6163	-0.0805	-21.9510
C	12	39	34	3	5.9346	3.6999	-14.4363	8.4856	5.0182	-15.5641	7.4652	4.1147	-11.9749	9.1280	2.3367	-20.4904
T	13	39	36	1	3.2127	-0.8643	-9.4567	2.7492	6.2714	-8.8035	4.0964	7.4474	-8.9050	-0.8633	2.8367	-9.3876
	14	27	36	2	6.6413	2.4763	-8.0840	8.5632	3.2763	-13.1552	4.5708	7.8018	-8.0086	6.7499	6.7681	-8.6182
	15	64	38	3	1.8806	8.0397	-9.8165	6.8687	16.7724	-31.5464	9.7866	7.6869	-13.7192	13.9854	14.4350	-30.9581
	16	58	34	2	3.5979	7.1770	-13.6476	11.7422	9.1784	-21.1376	3.8229	9.1922	-12.8419	15.5400	9.4816	-25.5967
	17	53	34	3	6.1553	7.3725	-12.1735	12.9597	11.9624	-22.8476	3.0898	4.5877	-5.4568	17.1336	9.4552	-20.8111
	18	45	34	3	2.7526	5.4562	-0.3103	6.7355	8.6688	-16.8237	-1.4698	3.8810	-3.3302	9.4523	10.6624	-18.5743
	19	54	36	2	0.6052	0.7860	-13.2823	6.7185	4.6197	-15.5247	5.6386	7.0760	-12.4249	6.7661	3.8800	-14.1414
	20	43	34	3	5.7606	6.4904	-8.4185	4.0564	5.4185	-10.4138	4.4228	5.7816	-7.1439	10.8710	2.3952	-18.9573

C16	Outer C17	C18	C19	Upper C20	C21	C22	Inner C23	C24	C25	Nipple C26	C27	C28
DD-DU	HH-HD	UU-UH	DD-DU	HH-HD	UU-UH	DD-DU	HH-HD	UU-UH	DD-DU	HH-HD	UU-UH	Ptosis
7.3343	-4.0309	1.7468	8.6059	-2.1153	-3.9757	12.1287	-2.8577	-1.8220	8.4085	-9.2092	-3.9130	3
7.5272	-3.4394	-1.2262	4.6989	-4.8900	-6.4425	13.3528	-3.3734	-12.6357	12.5787	-16.2758	-9.5637	3
7.4120	-1.9744	-3.8479	11.2679	-5.6083	-6.5551	5.4480	-1.1566	-4.0498	16.8638	-2.4167	-10.1696	3
10.2664	-2.7181	-3.3969	10.6802	-9.2514	-13.8251	8.5942	-1.1968	-1.6377	21.1763	-7.2976	-9.4697	4
4.7407	-2.7299	1.6628	11.6281	-3.7415	-4.9673	9.8401	-3.4790	-4.3182	9.4734	-1.8467	-2.9194	1
7.2077	-3.3072	-3.6570	13.2382	-3.6736	-3.0184	12.8795	-2.6449	-4.6231	13.7613	-1.3259	0.1214	2
10.3507	-3.8097	-4.7573	13.2544	-9.7066	-5.9539	10.7159	-5.9297	-4.7213	17.2079	-11.4996	-8.9860	2
-2.3480	0.2972	1.8055	6.3739	-7.5830	-6.6857	10.8159	-4.3206	-3.9672	8.9632	-2.4973	-3.3902	1
14.2724	-10.2986	-8.3762	16.7394	-14.2299	-5.6433	9.1608	-3.4400	-3.2052	23.5065	-5.7680	-4.8135	3
10.8970	-5.6487	-7.4404	17.3534	-8.7218	-11.0300	7.7145	-2.3548	-3.9191	22.9912	-9.0160	-10.7151	2
4.2872	-3.0656	-2.3170	7.6346	-6.9102	-5.3520	4.2885	-1.1237	-2.6886	5.6680	-16.9728	-17.3831	2
13.8863	-11.3134	-6.9326	15.8301	-12.1435	-7.2934	9.7069	-6.7489	-3.4851	18.1415	-20.8315	-10.1625	3
6.0641	-5.3388	-6.2196	11.0714	-5.2596	-8.3626	9.9536	-5.4377	-4.9456	7.3784	-12.9625	-5.1585	2
6.8609	-4.6146	-0.9374	13.6066	-10.3839	-4.8006	9.3513	-3.2112	-3.0212	12.1171	-3.6863	-2.7200	3
13.0653	-6.1735	-5.0819	20.5988	-11.5548	-17.1954	14.1963	-9.7287	-6.2035	28.7908	-15.9800	-13.4887	4
12.2401	-5.1057	-5.7888	21.1547	-14.7368	-10.0948	13.9049	-4.8875	-7.1120	27.0047	-14.9503	-12.4353	3
21.3570	-10.5115	-9.3244	23.3157	-13.3298	-11.5224	6.3039	-2.5225	-4.6035	28.1599	-12.5843	-6.4110	3
9.2588	-0.7187	0.6422	15.8064	-11.2996	-8.6547	6.7310	-2.0778	-1.8015	17.4591	-15.5753	-10.3572	4
-2.6825	-3.9445	-2.8749	11.5926	-9.7233	-6.3232	13.6769	-6.0205	-6.5312	12.1994	-8.3069	-6.7376	3
8.7609	-2.8636	-3.3765	11.3955	-6.6143	-7.6092	7.8788	-2.8582	-4.8077	18.1831	-18.9218	-7.0475	3

Table 4.10 The measurement table for measurement 12, the upper medial to lower lateral diagonal of the study mark. The values in C4-C27 are the posture distortion percentage values.

					Outer			Upper			Inner			Nipple	
		C1 Age	C2 Bust	C3 Cup	C4 DD-DH	C5 HH-HU	C6 UU-UD	C7 DD-DH	C8 HH-HU	C9 UU-UD	C10 DD-DH	C11 HH-HU	C12 UU-UD	C13 DD-DH	C14 HH-HU	C15 UU-UD
	1	50	32	1	-0.78270	-3.18040	1.35340	-1.0810	-7.65960	5.4394	-4.76800	-12.6153	9.12250	-3.78500	-3.13600	5.2052
	2	42	36	1	-2.34550	3.51600	-2.09230	-8.4119	-5.41540	1.8452	-4.51230	-4.4021	2.83080	3.45000	-3.21570	-6.1868
	3	29	36	2	-1.05360	0.07898	1.60735	-2.7206	-2.18886	-0.2624	0.67865	1.1089	0.41103	1.96852	4.14120	-3.2221
	4	58	40	3	-1.41551	-0.34176	-1.31580	-0.0650	-1.14060	-9.4765	-1.18699	-0.4367	-1.67274	2.36150	0.96220	-9.2948
	5	20	34	1	-5.18460	-2.14710	-0.56940	-3.9263	-6.50590	5.8998	2.05210	-8.2309	3.54660	0.76930	-4.40330	2.9202
	6	20	34	2	0.31150	1.05020	-0.62420	-4.7045	-4.88990	13.6301	1.39300	-6.5342	0.18080	3.07450	1.82340	-0.8231
S	7	30	36	5	0.55780	2.83490	-4.34180	-4.7871	-4.90360	1.1778	3.72150	-4.8416	0.55870	4.74930	2.37090	-6.5730
U	8	29	36	1	-0.88630	1.76880	0.48930	-9.5818	-5.77520	1.1757	-4.23580	-4.2355	4.23220	-2.43040	-0.89670	1.9180
B	9	46	38	3	-5.56400	0.77212	-1.52850	-0.9111	-4.31664	-4.2343	5.14837	0.0147	-1.10970	4.03040	0.15010	-3.7220
J	10	35	36	2	-3.22510	-0.25270	2.80120	-4.3740	-4.44870	2.4945	-1.41880	-0.5284	-2.36170	2.67010	1.72150	-3.7481
E	11	32	38	2	0.90490	0.54460	-1.04280	-4.3997	-1.78200	2.8396	-2.52110	-0.0518	1.16950	1.61650	-2.58380	-12.8800
C	12	39	34	3	-1.87305	1.16245	-5.45430	-3.7408	-1.11691	-0.1619	-2.11174	-1.1186	-0.22300	0.80690	-2.73630	-4.3871
T	13	39	36	1	-0.21430	0.25710	-0.40580	-12.0580	-3.93570	6.1378	-4.63700	-6.9691	6.40090	-6.58390	-7.01860	1.6256
	14	27	36	2	-2.77270	0.34290	0.68740	-4.9749	-6.91390	7.2976	-1.98510	-7.1082	2.09610	0.50160	-0.59710	-2.9857
	15	64	38	3	1.91920	-1.51550	-3.01440	-11.7139	-9.52530	8.0409	2.29330	-0.4339	-2.66460	-2.34150	-2.33440	-4.9687
	16	58	34	2	-0.05100	0.89810	-3.15070	-8.3518	-3.99380	-1.3000	2.88730	-4.3323	0.16420	4.42370	-1.08370	-11.8325
	17	53	34	3	-1.71570	-0.22040	-1.71560	-4.4563	-3.08220	-4.8511	-4.34650	-6.2832	-1.00220	4.70400	-2.67340	-11.9927
	18	45	34	3	-0.30116	-2.18180	0.17950	-2.6827	-4.80326	-3.8982	-1.74508	-3.3398	0.95658	0.10430	1.54420	-8.2569
	19	54	36	2	-0.02250	2.64110	-1.15600	-3.4126	-1.38627	0.6507	0.52068	-3.5450	-1.31740	0.05870	-2.00871	-1.8900
	20	43	34	3	3.73430	2.06120	-4.46870	-12.3532	-5.18180	4.3858	0.43020	-3.6386	5.59200	1.95210	-0.22850	-4.5458

	Outer			Upper			Inner			Nipple		
C16 DD-DU	C17 HH-HD	C18 UU-UH	C19 DD-DU	C20 HH-HD	C21 UU-UH	C22 DD-DU	C23 HH-HD	C24 UU-UH	C25 DD-DU	C26 HH-HD	C27 UU-UH	C28 Ptosis
-4.0151	-3.67580	4.38770	-11.3247	1.76700	3.57720	-14.5841	-0.03750	5.94620	-12.4076	6.62460	5.5399	3
-3.1534	0.33450	-1.11310	-13.0893	5.47320	1.40900	-12.1172	4.65320	1.57270	-5.8329	-4.30460	1.1255	3
0.2079	1.65853	0.42337	-3.9402	1.90337	1.13686	0.0730	1.09444	-1.16706	4.9286	2.82957	-3.6650	3
0.4648	0.16724	-2.06357	1.5467	-2.23070	-4.01430	-0.8639	1.73192	-0.55999	4.5745	-0.99300	-4.7402	4
-6.0108	-1.33060	1.95950	-14.6972	2.48760	4.58030	-6.5234	1.24410	6.51700	-5.4529	-1.73040	5.4575	1
1.5945	-1.20440	0.43330	-11.6970	3.02530	7.15690	-3.5096	-0.84390	2.87880	3.8638	1.68020	2.3769	2
3.2147	-1.13100	-3.40880	-10.7875	0.84920	1.54310	5.7461	1.98040	-3.35240	4.5228	-2.37090	-1.6192	2
1.9191	1.48730	-0.77840	-13.3084	2.63860	1.24310	-9.0494	3.84840	5.96080	-2.4919	0.61840	1.1256	1
-4.7648	1.35310	-2.15570	-2.7711	-1.79980	-1.52550	-0.4303	0.32397	0.11680	5.2132	0.38265	-0.8072	3
-1.8683	1.31570	0.04430	-10.3892	5.65500	2.65730	-2.3746	-0.99730	-2.42960	5.1038	1.88840	-4.3703	2
2.5761	0.16930	-0.98410	-7.5693	0.66550	1.58410	-2.6911	0.45160	0.52140	0.2521	-9.89470	-12.0409	2
-0.4373	1.14790	-4.95440	-6.6830	5.41550	-1.57490	-2.0006	0.29633	0.63936	0.4971	-3.50130	-4.8762	3
-0.5714	-1.25610	-2.01450	-16.2468	5.85530	1.23350	-10.8271	3.99200	3.51320	-13.9246	-0.08810	0.4552	2
-2.7507	4.26090	-0.54690	-12.4107	5.01120	3.27920	-9.2639	0.59600	2.29260	-0.1863	1.28760	0.0291	3
-0.4331	1.81280	-2.99260	-24.1453	9.51000	5.15540	-0.5970	-7.89030	0.96690	-5.4538	-1.38280	0.1529	4
0.0583	1.22600	-3.22210	-18.1140	1.40260	0.92760	-2.9448	-3.11220	1.55610	2.5467	-6.48710	-3.9646	3
-2.3961	3.51130	-0.72270	-9.5084	-1.48430	-2.37660	-6.5576	-2.38840	0.00750	2.7359	-3.44150	-4.2100	3
0.3232	-1.52357	-0.45945	-8.3027	-2.01190	0.42910	-6.5139	-2.12038	2.20462	-2.1094	-5.87390	-3.2440	4
3.8078	0.40460	-0.67010	-6.6197	2.19190	0.88740	-2.8042	-1.36054	1.09154	-0.0954	-0.40610	-2.0140	3
5.1014	0.73250	-2.12210	-14.3463	8.04400	-1.43260	-2.2413	-1.47680	6.32140	0.5909	-2.79370	-0.9973	3

Table 4.11 **The measurement table for measurement 15, the upper lateral to lower medial diagonal of the study mark. The values in C4-C27 are the posture distortion percentage values.**

Subject	Age (years)	Bust Size (inches)	Cup Size	Ptosis Index
A	50	32	1	3
B	42	36	1	3
C	29	36	2	3
D	58	40	3	4
E	20	34	1	1
F	20	34	2	2
G	30	36	5	2
H	29	36	1	1
I	46	38	3	3
J	35	36	2	2
K	32	38	2	2
L	39	34	3	3
M	39	36	1	2
N	27	36	2	3
O	64	38	3	4
P	58	34	2	3
Q	53	34	3	3
R	45	34	3	4
S	54	36	2	3
T	43	34	3	3

Legend

cup size	
A	1
B	2
C	3
D	4
DD	5

Table 4.12 **Subject data for the 20 individuals** (cup size was converted to a numerical scale to assist analysis)

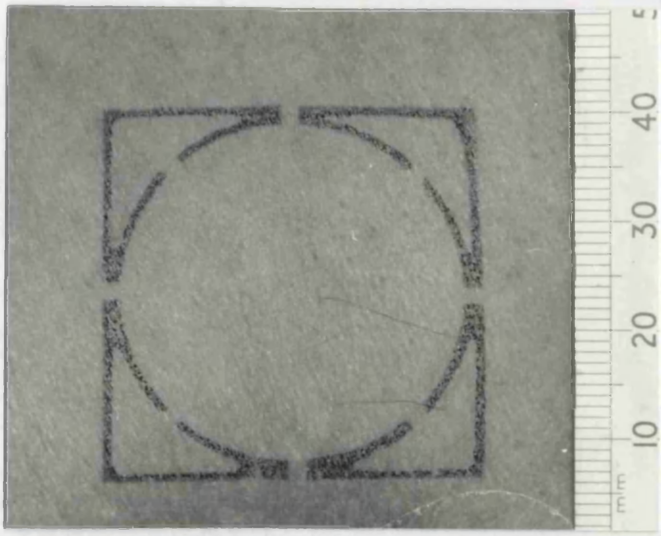


Figure 4.7a The study mark photographed with the arm in the same position as the mark had been recorded - down in this print

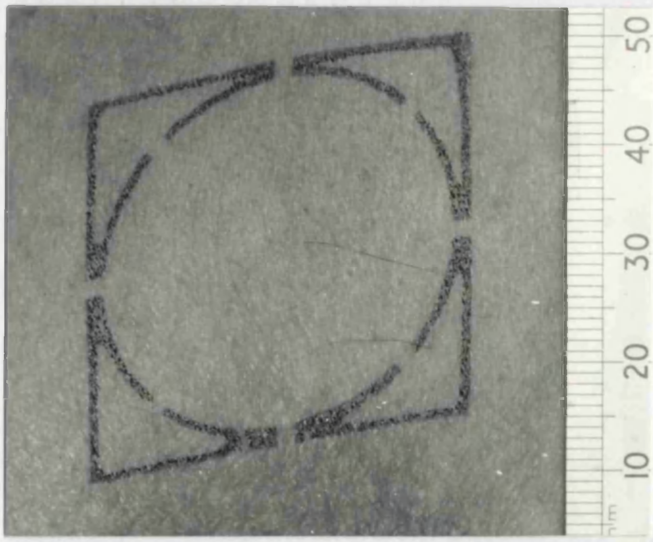


Figure 4.7b The same study mark photographed with the arm horizontal

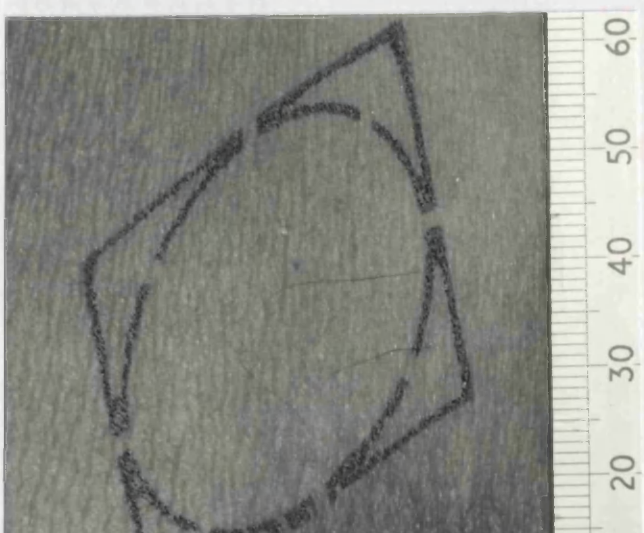


Figure 4.7c The same study mark photographed with the arm up

Measurement	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A-B	32.65	32.27	32.32	32.32	32.27	32.46	32.460	32.4133	32.3900	32.366	32.3817
H-S	23.26	23.26	23.40	23.54	23.41	23.27	23.260	23.3067	23.3650	23.374	23.3567
J-Q	31.11	30.85	30.86	30.98	30.98	31.29	30.980	30.9400	30.9500	30.956	31.0117
K-P	23.55	23.54	23.42	23.55	23.48	23.48	23.545	23.5033	23.5150	23.508	23.5033
C-D	32.53	32.90	32.65	32.72	32.60	32.46	32.715	32.6933	32.7000	32.680	32.6433
A-D	31.56	31.16	31.29	31.10	31.29	31.05	31.360	31.3367	31.2775	31.280	31.2417
O-T	21.85	22.35	22.10	21.85	22.04	22.04	22.100	22.1000	22.0375	22.038	22.0383
E-N	29.87	29.68	30.12	29.74	29.75	29.62	29.775	29.8900	29.8525	29.832	29.7967
G-L	23.06	23.30	23.25	23.24	23.03	23.16	23.180	23.2033	23.2125	23.176	23.1733
B-C	31.43	31.20	31.19	30.81	31.06	30.99	31.315	31.2733	31.1575	31.138	31.1133
F-I	19.87	20.01	20.04	20.04	20.14	20.00	19.940	19.9733	19.9900	20.020	20.0167
A-C	45.06	44.90	44.84	44.68	44.67	44.59	44.980	44.9333	44.8700	44.830	44.7900
N-O	20.21	20.03	19.98	20.18	20.30	20.18	20.120	20.0733	20.1000	20.140	20.1467
E-R	20.94	20.81	21.34	21.12	20.94	21.12	20.875	21.0300	21.0525	21.030	21.0450
B-D	45.58	45.30	45.30	45.11	45.30	45.21	45.440	45.3933	45.3225	45.318	45.3000
J-M	20.55	20.33	20.64	20.50	20.41	20.59	20.440	20.5067	20.5050	20.486	20.5033
E-F	1.38	1.52	1.32	1.34	1.39	1.46	1.450	1.4067	1.3900	1.390	1.4017
G-H	2.00	1.91	1.95	1.88	1.47	1.73	1.955	1.9533	1.9350	1.842	1.8233
I-J	1.46	1.57	1.44	1.51	1.38	1.45	1.515	1.4900	1.4950	1.472	1.4683
K-L	1.88	2.06	2.11	2.04	2.19	2.10	1.970	2.0167	2.0225	2.056	2.0633
M-N	1.91	2.10	1.93	1.65	1.75	1.74	2.005	1.9800	1.8975	1.868	1.8467
O-P	1.78	2.09	1.86	1.74	1.92	1.91	1.935	1.9100	1.8675	1.878	1.8833
Q-R	1.39	1.28	1.47	1.42	1.22	1.19	1.335	1.3800	1.3900	1.356	1.3283
S-T	1.77	1.69	1.87	1.78	1.86	1.60	1.730	1.7767	1.7775	1.794	1.7617

Legend		
	C1-C6	Measurement values
	C7	Cumulative mean value of C1 and C2
	C8	Cumulative mean value of C1, C2 and C3
	C9	Cumulative mean value of C1, C2, C3 and C4
	C10	Cumulative mean value of C1, C2, C3, C4 and C5
	C11	Cumulative mean value of C1, C2, C3, C4, C5 and C6
	C12-C16	Cumulative comparative mean values expressed as a percentage change of C1 and C7-C11 respectively

Table 4.13 **The repeat measurement values and the cumulative comparative analysis data**

Measurement	C12	C13	C14	C15	C16
A-B	0.58193	0.72486	0.79632	0.86983	0.82185
H-S	0.00000	-0.20063	-0.45142	-0.49011	-0.41559
J-Q	0.41787	0.54645	0.51430	0.49502	0.31608
K-P	0.02123	0.19816	0.14862	0.17834	0.19816
C-D	-0.56871	-0.50210	-0.52259	-0.46111	-0.34840
A-D	0.63371	0.70765	0.89512	0.88720	1.00866
O-T	-1.14416	-1.14416	-0.85812	-0.86041	-0.86194
E-N	0.31804	-0.06696	0.05859	0.12722	0.24551
G-L	-0.52038	-0.62157	-0.66132	-0.50304	-0.49147
B-C	0.36589	0.49846	0.86701	0.92905	1.00753
F-I	-0.35229	-0.52005	-0.60393	-0.75491	-0.73813
A-C	0.17754	0.28111	0.42166	0.51043	0.59920
N-O	0.44532	0.67623	0.54429	0.34636	0.31338
E-R	0.31041	-0.42980	-0.53725	-0.42980	-0.50143
B-D	0.30715	0.40954	0.56494	0.57481	0.61430
J-M	0.53528	0.21087	0.21898	0.31144	0.22709
E-F	-5.07246	-1.93237	-0.72464	-0.72464	-1.57005
G-H	2.25000	2.33333	3.25000	7.90000	8.83333
I-J	-3.76712	-2.05479	-2.39726	-0.82192	-0.57078
K-L	-4.78723	-7.26950	-7.57979	-9.36170	-9.75177
M-N	-4.97382	-3.66492	0.65445	2.19895	3.31588
O-P	-8.70787	-7.30337	-4.91573	-5.50562	-5.80524
Q-R	3.95683	0.71942	0.00000	2.44604	4.43645
S-T	2.25989	-0.37665	-0.42373	-1.35593	0.47081

Table 4.13 **The repeat measurement values and the cumulative comparative analysis data (contd)**

Measurement	Main Study			Random Study		
A-B	37.66	37.55	37.55	36.80	37.00	36.99
H-S	26.52	26.53	26.53	26.14	26.44	26.27
J-Q	35.14	34.76	34.93	34.62	34.72	34.57
K-P	25.48	25.38	25.58	25.23	25.52	25.46
C-D	34.68	34.89	34.84	34.50	34.50	34.32
A-D	31.73	31.43	31.36	31.39	31.44	31.24
O-T	22.59	22.29	22.59	22.31	22.33	22.42
E-N	28.97	29.07	29.04	28.63	28.37	28.61
G-L	21.55	21.52	21.40	21.37	21.53	21.45
B-C	29.42	29.13	29.20	28.67	28.69	28.64
F-I	22.15	22.11	22.15	21.88	21.96	22.10
A-C	46.30	46.25	46.30	45.37	45.51	45.37
N-Q	21.28	20.92	21.15	20.56	20.79	20.78
E-R	20.41	20.55	20.34	20.44	20.21	20.41
B-D	48.32	48.09	48.00	47.74	47.81	47.64
J-M	22.99	22.84	22.87	22.81	22.76	22.62
E-F	1.79	1.63	1.79	1.61	1.64	1.59
G-H	1.61	1.79	1.58	1.66	1.63	1.63
I-J	1.41	1.24	1.43	1.07	1.13	1.32
K-L	1.65	1.77	1.83	1.88	1.85	1.88
M-N	1.41	1.53	1.60	1.33	1.40	1.26
O-P	1.67	1.27	1.58	1.27	1.30	1.60
Q-R	1.42	1.72	1.65	1.57	1.40	1.69
S-T	1.62	1.67	1.72	1.79	1.89	1.65

Table 4.14 The measurement values of the same photographic print from the main and random studies

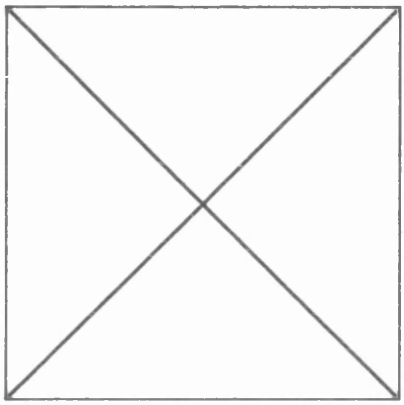


Figure 4.8 Maximum expansion and contraction percentage values of the six measurements in the 20 subjects

Measurement	Value	Arm Movement	Site	Subject	Age	Bust	Cup	Ptosis
Upper Horizontal								
Expansion	37.21	UU-UD	nipple	17	53	34	3	3
Contraction	27.53	DD-DU	nipple	4	58	40	3	4
Lower Horizontal								
Expansion	38.67	UU-UD	upper	15	64	38	3	4
Contraction	24.50	DD-DU	outer	13	39	36	1	2
Medial Vertical								
Expansion	14.87	HH-HD	nipple	15	64	38	3	4
Contraction	13.31	DD-DU	nipple	15	64	38	3	4
Lateral Vertical								
Expansion	26.63	DD-DU	outer	19	54	36	2	3
Contraction	25.23	UU-UD	outer	8	29	36	1	1
Upper Medial to Lower Lateral Diagonal								
Expansion	31.55	UU-UD	upper	15	64	38	3	4
Contraction	28.79	DD-DU	nipple	15	64	38	3	4
Upper Lateral to Lower Medial Diagonal								
Expansion	24.15	DD-DU	upper	15	64	38	3	4
Contraction	13.63	UU-UD	upper	6	20	34	2	2

Table 4.15 Maximum expansion and contraction percentage values and related subject data

Age/Bust size	0.183
Age/Cup size	O.219
Bust size/Cup size	0.217
Age/Ptosis	**0.741**
Bust size/Ptosis	0.179
Cup size/Ptosis	0.388

Legend	C1	Age
	C2	Bust size
	C3	Cup size
	C28	Ptosis

Table 4.16 The correlation coefficients of the age, bust size, cup size and ptosis index

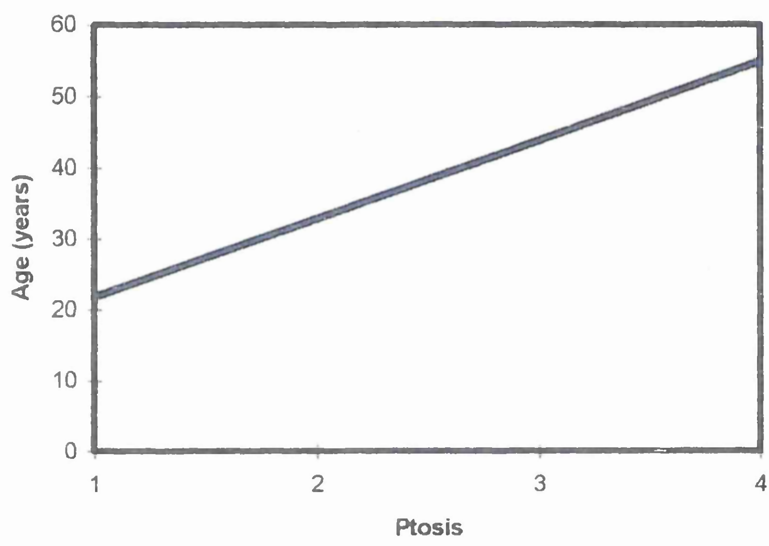


Figure 4.9 Correlation of age and ptosis index

Chapter 5

ANALYSIS OF THE HORIZONTAL MEASUREMENTS

Chapter 5

ANALYSIS OF THE HORIZONTAL MEASUREMENTS

5.1 INTRODUCTION

The main study of posture distortion in the female breast produced six measurement tables of data from the left breast. The analysis of the measurement tables of the two horizontal measurements commenced by studying the minimum and maximum posture distortion percentage values. The significance of age, bust size, cup size, ptosis and arm movement in relation to posture distortion in the horizontal axis were also assessed.

5.2 MATERIALS AND METHODS

The upper and lower edges of the die stamp were represented by the horizontal measurements 1 and 5 respectively. This enabled comparisons to be made between the horizontal measurements which were originally parallel and 34 mm apart.

The analysis of the horizontal measurement tables commenced by using Minitab to describe the values in C4-C27 as shown previously in Tables 4.6 and 4.7 The values selected were the minimum and maximum posture distortion percentage values. Posture distortion occurred as expansion and contraction with respect to change in the study marks due to arm movement.

The analysis focused on the arm movements which were considered to be most relevant to bite mark cases, these being horizontal to up, horizontal to down, up to down and down to up.

The relationships between the age, bust size, cup size, ptosis index and the posture distortion percentage values were examined using linear correlation tests within Minitab. Utilising Pearson's correlation coefficient (Altman, 1991) for a sample size of 20, a correlation of $> + 0.4438$ or $< - 0.4438$ is significant at the 5% level. The correlation coefficients which were assessed as statistically significant were plotted as graphs which demonstrated the relationship between the age, bust size, cup size, ptosis index and the posture distortion percentage values.

5.3 RESULTS

5.3.1 Minimum and maximum posture distortion percentage values

The minimum and maximum posture distortion percentage values of the two horizontal measurements in each of the four breast sites are shown in Table 5.1. The data illustrated the range of posture distortion exhibited by the 20 subjects. The upper and lower horizontal measurements demonstrated a similar pattern of distortion in each of the four sites. Furthermore, the minimum and maximum distortion values of the two horizontal measurements were found to be comparable in each of the four sites. In general terms, arm movement downwards produced expansion of the horizontal measurements in the four sites; by contrast, arm movement upwards produced contraction of the horizontal measurements in the four sites.

5.3.2 Posture distortion in relation to site

The maximum values of expansion and contraction of the two horizontal measurements in the four breast sites are shown in Table 5.2. The four sites demonstrated that the maximum expansion and contraction values of the horizontal measurements were produced by the most extensive arm movements, up to down and down to up respectively. The maximum expansion values of the two horizontal measurements were comparable in each of the four sites. The maximum contraction values of the two horizontal measurements were comparable in each of the four sites. The findings corresponded with the minimum and maximum distortion values.

The maximum expansion and contraction values of the upper and lower measurements were comparable in the outer site. The values ranged from 24.50% to 27.78%. The maximum expansion and contraction values of the upper and lower measurements were similar in the inner site. The values ranged from 14.19% to 20.49%. The maximum expansion values of the horizontal measurements were comparable in the upper and nipple sites, the range being from 33.23% to 38.67%. The maximum expansion values were higher than the maximum contraction values in the upper and nipple sites. The maximum expansion and contraction values were lowest in the inner site.

5.3.3 Posture distortion in relation to age, bust size, cup size and ptosis

The correlation coefficients of the age, bust size, cup size and ptosis index in relation to posture distortion in each of the four breast sites are shown in Table 5.3. The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface.

Age was significantly correlated with distortion in the outer, upper and nipple sites. Age appeared to have a greater influence in the upper and nipple sites. A significant correlation of age with distortion occurred in the outer site with distortion of the upper measurement produced by the most extensive arm movement, down to up. In the upper site, the least extensive arm movement, horizontal to down, showed a significant correlation of age with distortion of the lower measurement. In addition, significant correlations of age with distortion were found in the horizontal measurements due to the most extensive arm movement, up to down. The correlation was greater for the lower measurement, this being nearer the nipple. At the nipple site, significant correlations of age with distortion were noted in the horizontal measurements produced by the most extensive arm movement, up to down. A significant correlation of age with distortion also occurred in the lower measurement due to the most extensive arm movement, down to up. The significant correlations of age with distortion of the horizontal measurements were produced by the most extensive arm movements, with one exception. The significant correlations of age with distortion of the horizontal measurements in the upper and nipple sites were thought to be related to the selected plane of arm movement, namely, vertically by the subject's side.

Bust size showed no significant correlation with distortion in any site.

Cup size was significantly correlated with distortion in the outer, inner and nipple sites. A significant correlation of cup size with distortion occurred in the outer site with distortion of the lower measurement produced by the most extensive arm movement, up to down. In the inner site, cup size appeared to have a greater influence. Significant correlations were found with the least extensive arm movement, horizontal to up, for the distortion of the horizontal measurements. The most extensive arm movement, up to down, also showed a significant correlation of cup size with distortion of the lower measurement. At the nipple site, significant correlations of cup size with distortion were noted in the upper measurement due to the most extensive arm movements, up to down and down to up. The significant correlations of cup size with distortion of the horizontal measurements were produced mainly by the most extensive arm movements.

The ptosis index was significantly correlated with distortion in the outer, upper and nipple sites. A significant correlation of ptosis with distortion occurred in the outer site with distortion of the upper measurement produced by the most extensive arm movement, down to up. In the upper site, a significant correlation was found with the most extensive arm movement, up to down, for the distortion of the lower measurement. At the nipple site, the ptosis index appeared to have a greater influence. Significant correlations of ptosis with distortion were noted in the horizontal measurements produced by the most extensive arm movement, up to down.

The significant correlations of ptosis with distortion of the horizontal measurements were produced exclusively by the most extensive arm movements. The statistical correlations of age with distortion and ptosis with distortion were comparable in the outer, upper and nipple sites.

5.3.4 Posture distortion in relation to arm movement

The correlation coefficients of the arm movement in relation to posture distortion in each of the four breast sites are shown in Table 5.4 The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in the bold italicised typeface. The arm movements horizontal to up and horizontal to down showed no significant correlation in any site. The arm movements up to down and down to up were significantly correlated with distortion of the horizontal measurements in the outer and nipple sites and with distortion of the upper measurement in the upper site. The significant correlations of arm movement with distortion of the horizontal measurements were produced exclusively by the most extensive arm movements.

5.3.5 Significant correlations

The significance of the age, cup size and ptosis index were demonstrated by plotting the statistically significant correlation coefficients of the subjects' data and the posture distortion percentage values as graphs. The statistically significant correlation coefficients are highlighted in bold italicised typeface in Tables 5.3 and 5.4.

Age and the posture distortion percentage values were positively correlated with the arm movement down to up and inversely correlated with the arm movements up to down and horizontal to down. An increase in age was related to an increase in the magnitude of distortion produced by the arm movements up to down, down to up and horizontal to down (Figure 5.1).

Cup size and the posture distortion percentage values were positively correlated with the arm movements up to down and down to up and inversely correlated with the arm movements up to down and horizontal to up. An increase in cup size was related to an increase in the magnitude of distortion produced by the arm movements up to down and down to up (Figure 5.2). An increase in cup size was related to a decrease in the magnitude of distortion produced by the arm movements up to down and horizontal to up (Figure 5.3); the graphs of the arm movement horizontal to up also demonstrated an increase in the magnitude of distortion related to a subject with cup size 5 (Table 4.6 C11; Table 4.7 C11).

Ptosis and the posture distortion percentage values were positively correlated with the arm movement down to up and inversely correlated with the arm movement up to down. An increase in the ptosis index was related to an increase in the magnitude of distortion produced by the arm movements up to down and down to up (Figure 5.4).

5.4. DISCUSSION

Posture distortion was produced by arm movement in a selected plane, namely, vertically by the subject's side. The selected plane has a specific anatomical relationship with the horizontal axis in each of the four breast sites. Consequently, the posture distortion values were related to a specific anatomical relationship in each site. The extent and direction of arm movement, within the selected plane, were subject to variation. In this way, the influence of arm movement was assessed.

The minimum and maximum distortion values of the two horizontal measurements were comparable in each of the four sites. Therefore, distortion in the horizontal axis within the upper and lower edges of the study marks was relatively uniform in each of the four breast sites. Arm movement in opposite directions produced comparable expansion and contraction values in the outer site and less comparable expansion and contraction values in the upper, inner and nipple sites. In effect, alternating the direction of arm movement produced a mirror image of expansion and contraction in the four sites. In general terms, arm movement downwards produced expansion of the horizontal measurements in the four sites; by contrast, arm movement upwards produced contraction of the horizontal measurements in the four sites.

The maximum expansion and contraction values were produced by the most extensive arm movements, up to down and down to up respectively in the four breast sites. It was thought that the two horizontal measurements underwent distortion in proportion to arm movement in the four sites. However, it was noted that distortion in the horizontal axis within the upper and lower edges of the study marks was relatively uniform in each of the four sites. Consequently, it was considered that the proportional relationship was relatively uniform in the horizontal axis in each of the four breast sites.

The significant correlations of age with distortion of the horizontal measurements were produced by the most extensive arm movements, with one exception. The significant correlations of cup size with distortion of the horizontal measurements were produced mainly by the most extensive arm movements. The significant correlations of ptosis and arm movement with distortion of the horizontal measurements were produced exclusively by the most extensive arm movements. In view of these findings, it was considered that the significance, in the horizontal axis, of the most extensive arm movements was related to the selected plane of arm movement.

The initial stages of the main study (Chapter 4) demonstrated that age and ptosis were positively correlated; an increase in age was related to an increase in ptosis. This is consistent with the findings that the statistical correlations of age with distortion and ptosis with distortion were comparable in the horizontal axis.

5.5. CONCLUSIONS

Distortion in the upper horizontal axis was comparable with the lower horizontal axis in the four sites. Therefore, distortion in the horizontal axis was relatively uniform in each of the four breast sites. In general terms, the horizontal axis in the four breast sites expanded in response to arm movement downwards and contracted in response to arm movement upwards. The horizontal axis in the outer, upper and nipple sites underwent maximum distortion of 27.78%, 38.67% and 37.95% respectively in response to the most extensive arm movement, up to down. The horizontal axis in the inner site underwent maximum distortion of 20.49% in response to the most extensive arm movement, up to down.

The clinical significance of age was that an increase in the subjects' age was related to an increase in the magnitude of distortion in the horizontal axis in the outer, upper and nipple sites. The clinical significance of ptosis was that an increase in the ptosis index was related to an increase in the magnitude of distortion in the horizontal axis in the outer, upper and nipple sites. No clinical significance of bust size was established in the horizontal axis in the four breast sites. The clinical significance of cup size was contradictory - an increase in the subjects' cup size was related to an increase and a decrease in the magnitude of distortion in the horizontal axis in the outer, inner and nipple sites. The clinical significance of arm movement was that only the most extensive arm movements were significant in the horizontal axis in the outer, upper and nipple sites.

Arm movement		Upper Measurement Minimum	Upper Measurement Maximum	Lower Measurement Minimum	Lower Measurement Maximum
	DD-DH	0.99	12.16	1.87	13.59
Outer	HH-HU	2.69	13.61	3.52	17.26
	UU-UD	-8.65	-27.78	-4.90	-26.66
	DD-DH	-5.29	9.30	-1.05	13.13
Upper	HH-HU	-4.26	12.37	-4.28	9.64
	UU-UD	-2.32	-33.23	-5.49	-38.67
	DD-DH	-3.73	7.19	-0.89	7.05
Inner	HH-HU	7.91	-10.29	8.11	-12.03
	UU-UD	5.62	-20.49	4.85	-16.87
	DD-DH	2.43	16.48	3.86	15.01
Nipple	HH-HU	-0.82	13.78	0.57	12.40
	UU-UD	-8.12	-37.21	-7.21	-37.95
	DD-DU	6.02	25.47	9.51	24.50
Outer	HH-HD	-2.61	-16.34	-1.51	-14.49
	UU-UH	4.71	-11.45	-0.64	-13.34
	DD-DU	-7.09	20.68	-0.58	21.01
Upper	HH-HD	1.05	-14.85	-0.90	-21.57
	UU-UH	-1.21	-19.14	-1.64	-20.68
	DD-DU	-0.29	14.91	2.51	14.19
Inner	HH-HD	0.70	-6.63	1.82	-7.32
	UU-UH	-0.08	-9.92	-0.45	-11.56
	DD-DU	5.58	27.53	5.38	23.15
Nipple	HH-HD	-1.92	-23.64	-0.02	-20.19
	UU-UH	1.13	-25.31	2.82	-17.43

Table 5.1 The minimum and maximum posture distortion percentage values of the horizontal measurements

Site	Expansion		Contraction	
Outer	***27.78***	26.66	***25.47***	24.50
Upper	***33.23***	38.67	***20.68***	21.01
Inner	***20.49***	16.87	***14.91***	14.19
Nipple	***37.21***	37.95	***27.53***	23.15

Table 5.2 The maximum posture distortion percentage values of the horizontal measurements (upper measurement in italics)

		Upper Measurement	Lower Measurement		Upper Measurement	Lower Measurement
	C1,C5	0.331	0.157	C1,C6	-0.413	-0.065
	C2,C5	0.213	-0.397	C2,C6	0.071	0.352
	C3,C5	0.248	-0.229	C3,C6	0.011	***0.447***
Outer	C28,C5	0.152	-0.069	C28,C6	-0.104	0.219
	C1,C17	-0.227	0.112	C1,C16	***0.548***	0.033
	C2,C17	0.360	0.262	C2,C16	0.189	-0.401
	C3,C17	0.307	0.428	C3,C16	0.324	-0.296
	C28,C17	-0.024	0.359	C28,C16	***0.474***	-0.012
	C1,C8	0.198	0.239	C1,C9	***-0.747***	***-0.824***
	C2,C8	0.023	0.046	C2,C9	-0.331	-0.293
	C3,C8	-0.141	0.202	C3,C9	-0.232	-0.409
Upper	C28,C8	-0.102	0.346	C28,C9	-0.431	***-0.685***
	C1,C20	-0.305	***-0.522***	C1,C19	0.257	0.168
	C2,C20	-0.236	-0.142	C2,C19	0.269	0.165
	C3,C20	-0.266	-0.335	C3,C19	-0.093	0.275
	C28,C20	-0.140	-0.306	C28,C19	0.072	0.280
	C1,C11	0.146	0.283	C1,C12	-0.406	-0.206
	C2,C11	0.092	-0.155	C2,C12	0.033	0.085
	C3,C11	***-0.563***	***-0.630***	C3,C12	0.330	***0.514***
Inner	C28,C11	0.054	0.245	C28,C12	-0.175	-0.061
	C1,C23	-0.408	0.138	C1,C22	0.068	-0.001
	C2,C23	-0.060	-0.004	C2,C22	0.306	-0.013
	C3,C23	-0.212	-0.079	C3,C22	0.195	0.078
	C28,C23	-0.351	0.359	C28,C22	-0.024	0.006
	C1,C14	0.257	0.301	C1,C15	***-0.675***	***-0.742***
	C2,C14	0.247	0.137	C2,C15	-0.309	-0.299
	C3,C14	0.074	0.028	C3,C15	***-0.453***	-0.304
Nipple	C28,C14	0.299	0.414	C28,C15	***-0.596***	***-0.595***
	C1,C26	-0.307	-0.399	C1,C25	0.409	***0.510***
	C2,C26	0.058	0.038	C2,C25	0.303	0.197
	C3,C26	-0.130	-0.133	C3,C25	***0.498***	0.269
	C28,C26	-0.228	-0.309	C28,C25	0.373	0.394

Legend	C1	Age
	C2	Bust size
	C3	Cup size
	C28	Ptosis
	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 5.3 The correlation coefficients of age, bust size, cup size and ptosis in relation to posture distortion

		Upper Measurement	Lower Measurement		Upper Measurement	Lower Measurement
Outer	C5,C17	0.186	-0.287	C6,C16	***-0.468***	***-0.775***
Upper	C8,C20	-0.200	0.182	C9,C19	***-0.447***	-0.333
Inner	C11,C23	-0.115	0.278	C12,C22	-0.100	-0.317
Nipple	C14,C26	0.295	0.426	C15,C25	***-0.446***	***-0.446***

Legend		
	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 5.4 The correlation coefficients of arm movement in relation to posture distortion

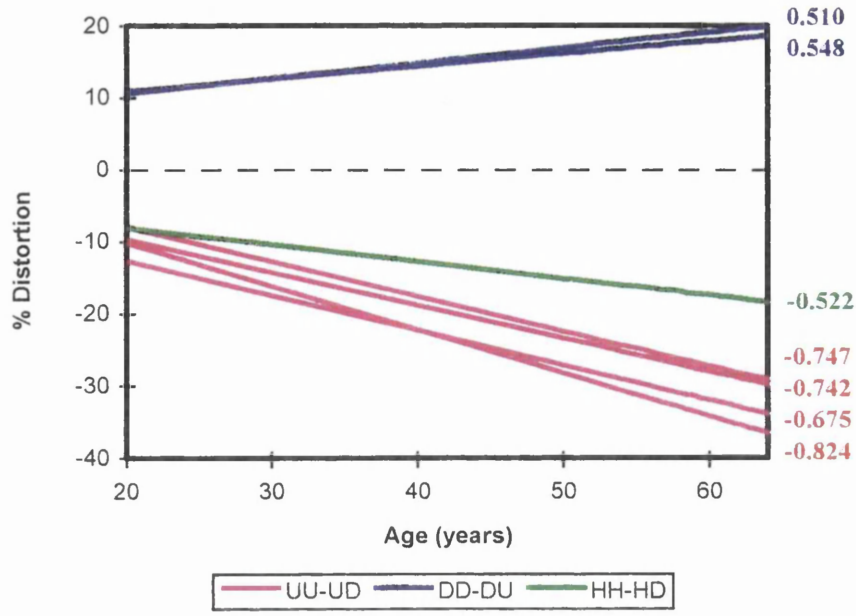


Figure 5.1 Correlation of age and posture distortion

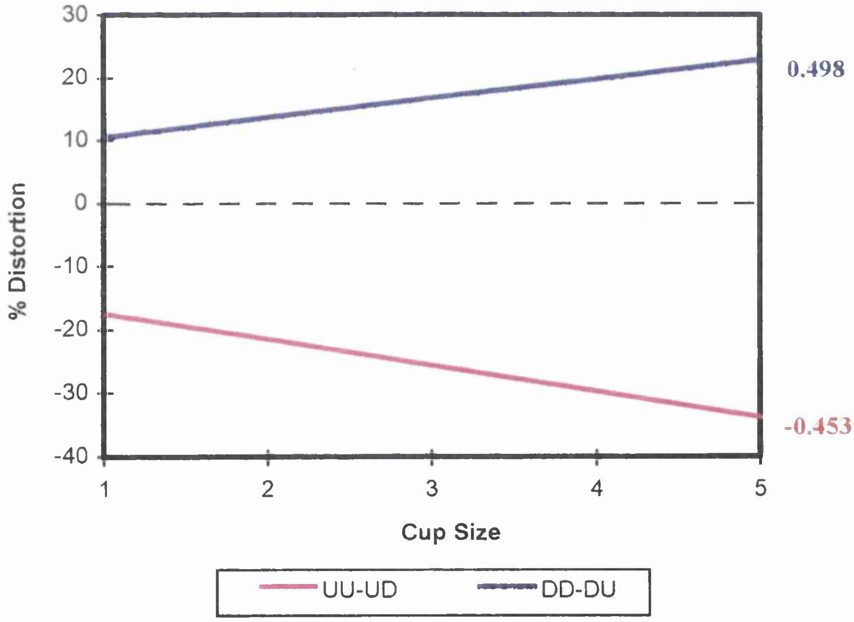


Figure 5.2 Correlation of cup size and posture distortion

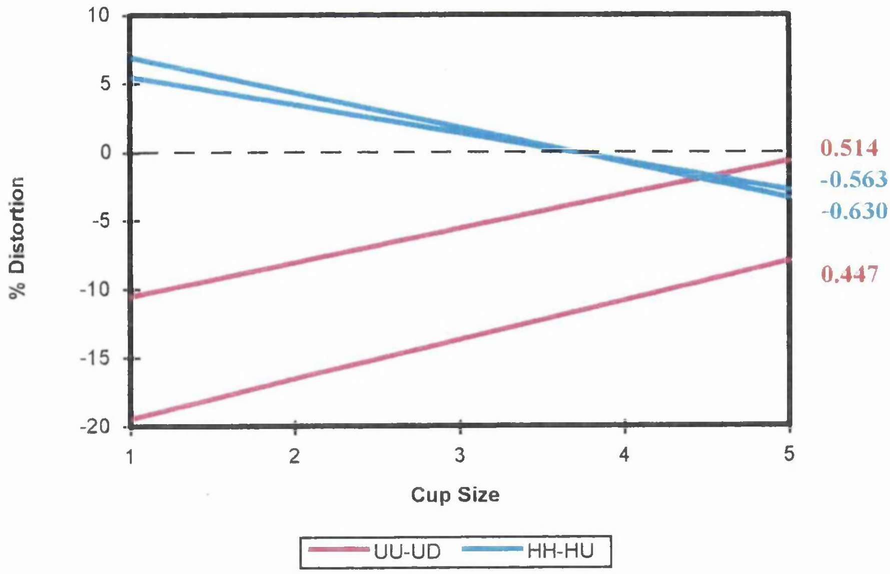


Figure 5.3 Correlation of cup size and posture distortion

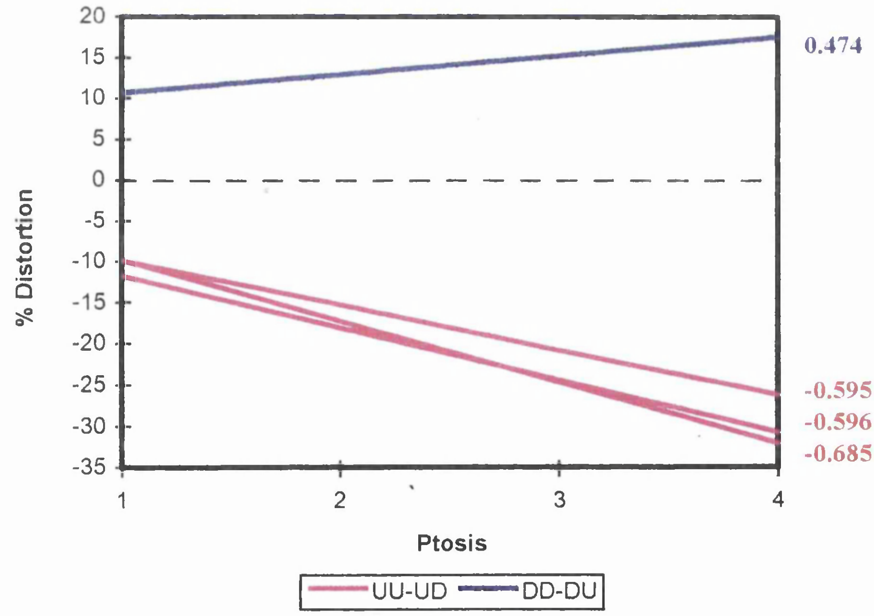


Figure 5.4 Correlation of ptosis index and posture distortion

Chapter 6

ANALYSIS OF THE VERTICAL MEASUREMENTS

Chapter 6

ANALYSIS OF THE VERTICAL MEASUREMENTS

6.1 INTRODUCTION

The main study of posture distortion in the female breast produced six measurement tables of data from the left breast. The analysis of the measurement tables of the two vertical measurements commenced by studying the minimum and maximum posture distortion percentage values. The significance of age, bust size, cup size, ptosis and arm movement in relation to posture distortion in the vertical axis were also assessed.

6.2 MATERIALS AND METHODS

The medial and lateral edges of the die stamp were represented by the vertical measurements 6 and 10 respectively. This enabled comparisons to be made between the vertical measurements which were originally parallel and 34mm apart.

The analysis of the vertical measurement tables commenced by using Minitab to describe the values in C4-C27 as shown previously in Tables 4.8 and 4.9. The values selected were the minimum and maximum posture distortion percentage values. Posture distortion occurred as expansion and contraction with respect to change in the study marks due to arm movement.

The analysis focused on the arm movements which were considered to be most relevant to bite mark cases, these being horizontal to up, horizontal to down, up to down and down to up.

The relationships between the age, bust size, cup size, ptosis index and the posture distortion percentage values were examined using linear correlation tests within Minitab. Utilising Pearson's correlation coefficient (Altman, 1991) for a sample size of 20, a correlation of > + 0.4438 or < - 0.4438 is significant at the 5% level. The correlation coefficients which were assessed as statistically significant were plotted as graphs which demonstrated the relationship between the age, bust size, cup size, ptosis index and the posture distortion percentage values.

6.3 RESULTS

6.3.1 Minimum and maximum posture distortion percentage values

The minimum and maximum posture distortion percentage values of the two vertical measurements in each of the four breast sites are shown in Table 6.1. The data illustrated the range of posture distortion exhibited by the 20 subjects. The medial and lateral vertical measurements demonstrated a similar pattern of distortion in the upper, inner and nipple sites. The pattern of distortion varied between the vertical measurements in the outer site. The minimum and maximum distortion values of the two vertical measurements varied in the outer and upper sites and were similar in the inner and nipple sites. The lateral measurement demonstrated higher distortion values than the medial measurement in the outer and upper sites. In general terms, arm movement downwards produced contraction of the vertical measurements in the outer and upper sites; by contrast, arm movement upwards produced expansion of the vertical measurements in the outer and upper sites. Arm movements downwards and upwards each produced expansion and contraction of the vertical measurements in the inner and nipple sites.

6.3.2 Posture distortion in relation to site

The maximum values of expansion and contraction of the two vertical measurements in the four breast sites are shown in Table 6.2. In general terms, the maximum distortion values of the vertical measurements in the outer and upper sites and of the lateral measurement in the nipple site were produced by the most extensive arm movements; the maximum distortion values of the vertical measurements in the inner site and of the medial measurement in the nipple site were produced by a variety of arm movements. The maximum expansion values of the two vertical measurements varied in the outer and upper sites and were similar in the inner and nipple sites. The maximum contraction values of the two vertical measurements varied in the outer and upper sites and were similar in the inner and nipple sites. The findings corresponded with the minimum and maximum distortion values.

The maximum expansion and contraction values of the medial measurement were similar in each of the four sites. The values ranged from 8.46% to 14.87%. The maximum expansion and contraction values of the lateral measurement were similar in the outer and upper sites. The values ranged from 19.23% to 26.63%. The maximum expansion and contraction values of the lateral measurement were similar in the inner and nipple sites. The values ranged from 10.08% to 18.03%. The maximum expansion and contraction values were demonstrated by the lateral measurement in the outer and upper sites.

6.3.3 Posture distortion in relation to age, bust size, cup size and ptosis

The correlation coefficients of the age, bust size, cup size and ptosis index in relation to posture distortion in each of the four breast sites are shown in Table 6.3. The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface.

Age was significantly correlated with distortion in the upper, inner and nipple sites. Age appeared to have a greater influence in the upper and inner sites. A significant correlation of age with distortion was found in the upper site with distortion of the lateral measurement produced by the least extensive arm movement, horizontal to up. In addition, a significant correlation of age with distortion occurred in the medial measurement due to the most extensive arm movement, up to down. In the inner site, significant correlations were found with the least extensive arm movement, horizontal to down, for the distortion of the vertical measurements. The correlation was greater for the lateral measurement, this being nearer the nipple. At the nipple site, a significant correlation of age with distortion was noted in the medial measurement produced by the least extensive movement, horizontal to down. The significant correlations of age with distortion of the vertical measurements were produced by the least extensive arm movements, with one exception.

Bust size was significantly correlated with distortion only in the inner site. Significant correlations of bust size with distortion occurred in the vertical measurements due to the least extensive arm movement, horizontal to up. Consequently, the significant correlations of bust size with distortion of the vertical measurements were produced exclusively by the least extensive arm movements.

Cup size was significantly correlated with distortion in the four sites. Cup size appeared to have maximum influence in the outer and nipple sites. In the outer site, significant correlations were found with the least extensive arm movements, horizontal to up and horizontal to down, for the distortion of the vertical movements. In addition, significant correlations of cup size with distortion occurred in the vertical measurements due to the most extensive arm movements, up to down and down to up. In the upper site, significant correlations were noted with the least extensive arm movements, horizontal to up and horizontal to down, for the distortion of the lateral measurement. In addition, a significant correlation of cup size with distortion was found in the lateral measurement due to the most extensive arm movement, up to down. The most extensive arm movement, down to up, also showed significant correlations of cup size with distortion of the vertical measurements. In the inner site, significant correlations of cup size with distortion occurred in the vertical measurements produced by the most extensive arm movement, down to up. At the nipple site, significant correlations were noted with the least extensive arm movements, horizontal to up and horizontal to down, for the distortion of the vertical measurements. In addition, significant correlations of cup size with distortion were found in the vertical measurements due to the most extensive arm movements, up to down and down to up. The significant correlations of cup size with distortion of the vertical measurements were produced by the least and most extensive arm movements. The significant correlations of cup size with distortion of the vertical measurements in the outer and nipple sites were thought to be related to the selected plane of arm movement, namely, vertically by the subject's side.

The ptosis index was significantly correlated with distortion in the upper and inner sites. Ptosis appeared to have the greatest influence in the upper site. A significant correlation of ptosis with distortion occurred in the upper site with distortion of the lateral measurement produced by the least extensive arm movement, horizontal to up. In addition, significant correlations of ptosis with distortion were noted in the lateral measurement due to the most extensive arm movements, up to down and down to up. In the inner site, a significant correlation of ptosis with distortion was found in the lateral measurement due to the least extensive arm movement, horizontal to down. The significant correlations of ptosis with distortion of the lateral measurement were produced equally by the least and most extensive arm movements. The statistical correlations of age with distortion and ptosis with distortion were comparable in the upper and inner sites and not in the nipple site.

6.3.4 Posture distortion in relation to arm movement

The correlation coefficients of the arm movement in relation to posture distortion in each of the four breast sites are shown in Table 6.4 The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface. Arm movement was significantly correlated with distortion in the four sites. Arm movement appeared to have maximum influence in the outer site. The arm movements horizontal to up and horizontal to down were significantly correlated with the vertical measurements in the outer site. The arm movements horizontal to up and horizontal to down were significantly correlated with the lateral measurement in the upper site. The arm movements up to down and down to up were significantly correlated with the vertical measurements in the four sites. The significant correlations of arm movement with distortion of the vertical measurements were produced mainly by the most extensive arm movements.

6.3.5 Significant correlations

The significance of the age, bust size, cup size and ptosis index were demonstrated by plotting the statistically significant correlation coefficients of the subjects' data and the posture distortion percentage values as graphs. The statistically significant correlation coefficients are highlighted in bold italicised typeface in Tables 6.3 and 6.4.

Age and the posture distortion percentage values were positively correlated with the arm movements up to down and horizontal to up and inversely correlated with the arm movement horizontal to down. An increase in age was related to an increase in the magnitude of distortion produced by the arm movements up to down and horizontal to down (Figure 6.1); the graphs of the arm movement horizontal to down also demonstrated a decrease in the magnitude of distortion with an increase in age of younger subjects (Table 4.8 C23, C26; Table 4.9 C23) An increase in age was related to a decrease in the magnitude of distortion produced by the arm movement horizontal to up (Figure 6.2).

Bust size and the posture distortion percentage values positively correlated with the arm movement horizontal to up. An increase in bust size was related to a decrease in the magnitude of distortion produced by the arm movement horizontal to up (Figure 6.3); the graph also demonstrated an increase in the magnitude of distortion associated with larger bust sizes (Table 4.8 C11). An increase in smaller bust sizes was related to a decrease in the magnitude of distortion produced by the arm movement horizontal to up; an increase in larger bust sizes was related to an increase in the magnitude of distortion produced by the arm movement horizontal to up (Figure 6.4; Table 4.9 C11).

Cup size and the posture distortion percentage values were positively correlated with the arm movements down to up and horizontal to up and inversely correlated with the arm movements up to down and horizontal to down. An increase in cup size was related to a decrease in the magnitude of distortion produced by the arm movements horizontal to up and horizontal to down (Figure 6.5); three of the graphs of the arm movement horizontal to up also demonstrated an increase in the magnitude of distortion associated with larger cup sizes (Table 4.8 C5; Table 4.9 C8, C14). An increase in cup size was related to a decrease in the magnitude of distortion produced by the arm movements up to down and down to up (Figure 6.6); three of the graphs of the arm movement up to down also demonstrated an increase in the magnitude of distortion associated with larger cup sizes (Table 4.8 C6, C15; Table 4.9 C15); five of the graphs of the arm movement down to up also demonstrated an increase in the magnitude of distortion associated with larger cup sizes (Table 4.8 C16, C22, C25; Table 4.9 C22, C25). An increase in cup size was related to an increase in the magnitude of distortion produced by the arm movements horizontal to up and horizontal to down (Figure 6.7); the graphs also demonstrated a decrease in the magnitude of distortion associated with smaller cup sizes (Table 4.8 C14, C17, C26; Table 4.9 C26).

Ptosis and the posture distortion percentage values were positively correlated with the arm movements down to up and horizontal to up and inversely correlated with the arm movements up to down and horizontal to down. An increase in the ptosis index was related to a decrease in the magnitude of distortion produced by the arm movements up to down, down to up and horizontal to up (Figure 6.8). An increase in the ptosis index was related to an increase in the magnitude of distortion produced by the arm movement horizontal to down (Figure 6.9); the graph also demonstrated a decrease in the magnitude of distortion associated with smaller ptosis indices (Table 4.9 C23).

6.4 DISCUSSION

Posture distortion was produced by arm movement in a selected plane, namely, vertically by the subject's side. The selected plane has a specific anatomical relationship with the vertical axis in each of the four breast sites. Consequently, the posture distortion values were related to a specific anatomical relationship in each site. The extent and direction of arm movement, within the selected plane, were subject to variation. In this way, the influence of arm movement was assessed.

The minimum and maximum distortion values of the two vertical measurements varied in the outer and upper sites and were similar in the inner and nipple sites. Therefore, distortion in the vertical axis within the medial and lateral edges of the study marks was variable in the outer and upper sites and was relatively uniform in the inner and nipple sites. The lateral measurement demonstrated higher distortion values than the medial measurement in the outer and upper sites. Arm movement in opposite directions produced comparable expansion and contraction values in the outer and upper sites and less comparable expansion and contraction values in the inner and nipple sites. In effect, alternating the direction of arm movement produced a mirror image of expansion and contraction in the four sites. In general terms, arm movement downwards produced contraction of the vertical measurements in the outer and upper sites; by contrast, arm movement upwards produced expansion of the vertical measurements in the outer and upper sites. Arm movements downwards and upwards each produced expansion and contraction of the vertical measurements in the inner and nipple sites.

The maximum expansion and contraction values, in general terms, were produced by the most extensive arm movements in the outer and upper sites and by a variety of arm movements in the inner and nipple sites. It was thought that the two vertical measurements underwent distortion in proportion to arm movement in the outer and upper sites. However, it was noted that distortion in the vertical axis within the medial and lateral edges of the study marks was variable in the outer and upper sites. Consequently, it was considered that the proportional relationship was variable in the vertical axis in the outer and upper sites. Similarly, it was thought that the two vertical measurements underwent distortion in a complex relationship to arm movement in the inner and nipple sites. However, it was noted that distortion in the vertical axis within the medial and lateral edges of the study marks was relatively uniform in the inner and nipple sites. Consequently, it was considered that the complex relationship was relatively uniform in the vertical axis in the inner and nipple sites.

The significant correlations of age with distortion of the vertical measurements were produced by the least extensive arm movements, with one exception. The significant correlations of bust size with distortion of the vertical measurements were produced exclusively by the least extensive arm movements. The significant correlations of cup size with distortion of the vertical measurements were produced by the least and most extensive arm movements. The significant correlations of ptosis with distortion of the lateral measurement were produced equally by the least and most extensive arm movements. The significant correlations of arm movement with distortion of the vertical measurements were produced mainly by the most extensive arm movements.

In view of these findings, it was considered that the significance, in the vertical axis, of the least and most extensive arm movements, was related to the selected plane of arm movement.

The initial stages of the main study (Chapter 4) demonstrated that age and ptosis were positively correlated; an increase in age was related to an increase in ptosis. This is consistent with the findings that the statistical correlations of age with distortion and ptosis with distortion were comparable in the vertical axis in two of three possible breast sites.

6.5 CONCLUSIONS

Distortion in the lateral vertical axis was greater that the medial vertical axis in the outer and upper sites. Therefore, distortion in the vertical axis was variable in the outer and upper sites. Distortion in the lateral vertical axis was comparable with the medial vertical axis and the inner and nipple sites. Therefore, distortion in the vertical axis was relatively uniform in the inner and nipple sites. In general terms, the vertical axis in the outer and upper sites contracted in response to arm movement downwards and expanded in response to arm movement upwards. The vertical axis in the inner and nipple sites expanded and contracted in response to arm movements downwards and upwards. The lateral vertical axis in the outer and upper sites underwent maximum distortion of 26.63% and 21.58% respectively in response to the most extensive arm movement, down to up. The lateral vertical axis in the inner and nipple sites underwent maximum distortion of 13.91% and 18.03% respectively in response to the arm movements, horizontal to down and down to up.

The clinical significance of age was contradictory - an increase in the subjects' age was related to an increase and a decrease in the magnitude of distortion in the vertical axis in the upper, inner and nipple sites. The clinical significance of ptosis was contradictory - an increase in the subjects' ptosis index was related to an increase and a decrease in the magnitude of distortion in the vertical axis in the upper and inner sites. The clinical significance of bust size was contradictory - an increase in the subjects' bust size was related to an increase and a decrease in the magnitude of distortion in the vertical axis in the inner site. The clinical significance of cup size was contradictory - an increase in the subjects' cup size was related to an increase and a decrease in the magnitude of distortion in the vertical axis in the four breast sites. The clinical significance of arm movement was that the least and most extensive arm movements were significant in the vertical axis in the outer and upper sites and only the most extensive arm movements were significant in the vertical axis in the inner and nipple sites.

Arm Movement		Medial Measurement Minimum	Medial Measurement Maximum	Lateral Measurement Minimum	Lateral Measurement Maximum
	DD-DH	1.56	-5.58	0.59	-15.12
Outer	HH-HU	3.78	-9.13	-0.87	-14.90
	UU-UD	-6.18	9.37	3.55	25.23
	DD-DH	2.09	-8.86	0.41	-17.19
Upper	HH-HU	2.38	-5.57	1.90	-7.65
	UU-UD	2.40	13.12	2.15	19.23
	DD-DH	-5.14	7.26	-7.76	8.95
Inner	HH-HU	4.18	-7.05	6.73	-8.25
	UU-UD	8.46	-10.50	-6.75	9.75
	DD-DH	9.83	-10.98	8.45	-11.96
Nipple	HH-HU	-5.40	7.94	4.68	-9.36
	UU-UD	-7.89	10.10	-8.70	9.68
	DD-DU	-9.96	10.46	2.50	-26.63
Outer	HH-HD	3.86	-7.48	1.25	13.34
	UU-UH	-3.81	7.00	0.85	12.95
	DD-DU	0.94	-13.55	-0.21	-21.58
Upper	HH-HD	-0.51	8.60	0.00	11.95
	UU-UH	-0.83	6.89	-1.77	8.59
	DD-DU	8.43	-8.91	-11.58	11.79
Inner	HH-HD	4.45	-11.30	3.16	-13.91
	UU-UH	-4.10	7.77	4.98	-6.35
	DD-DU	-12.69	13.31	10.08	-18.03
Nipple	HH-HD	2.34	-14.87	-5.36	5.67
	UU-UH	8.35	-9.13	-6.30	7.90

Table 6.1 **The minimum and maximum posture distortion percentage values of the vertical measurements**

Site	Expansion		Contraction	
Outer	***9.96***	26.63	***10.46***	25.23
Upper	***13.55***	21.58	***13.12***	19.23
Inner	***11.30***	13.91	***8.46***	11.79
Nipple	***14.87***	18.03	***13.31***	10.08

Table 6.2 The maximum posture distortion percentage values of the vertical measurements (medial measurement in italics)

		Medial Measurement	Lateral Measurement		Medial Measurement	Lateral Measurement
	C1,C5	0.041	0.100	C1,C6	-0.072	-0.138
	C2,C5	0.383	0.303	C2,C6	-0.195	-0.343
	C3,C5	***0.692***	***0.670***	C3,C6	***-0.661***	***-0.708***
Outer	C28,C5	0.327	0.303	C28,C6	-0.194	-0.288
	C1,C17	-0.195	-0.166	C1,C16	0.235	0.134
	C2,C17	-0.069	-0.238	C2,C16	-0.009	0.221
	C3,C17	***-0.579***	***-0.717***	C3,C16	***0.585***	***0.664***
	C28,C17	-0.199	-0.414	C28,C16	0.271	0.317
	C1,C8	0.219	***0.567***	C1,C9	***0.525***	-0.186
	C2,C8	0.267	0.186	C2,C9	0.123	-0.228
	C3,C8	0.059	***0.504***	C3,C9	0.005	***-0.609***
Upper	C28,C8	0.133	***0.579***	C28,C9	0.176	***-0.452***
	C1,C20	0.214	-0.234	C1,C19	-0.271	0.257
	C2,C20	0.044	-0.242	C2,C19	-0.080	0.075
	C3,C20	-0.275	***-0.660***	C3,C19	***0.482***	***0.659***
	C28,C20	-0.209	-0.434	C28,C19	0.116	***0.510***
	C1,C11	0.343	0.109	C1,C12	-0.262	-0.040
	C2,C11	***0.560***	***0.639***	C2,C12	-0.432	-0.254
	C3,C11	0.327	0.294	C3,C12	-0.374	-0.381
Inner	C28,C11	0.340	0.298	C28,C12	-0.249	-0.365
	C1,C23	***-0.525***	***-0.589***	C1,C22	0.356	0.046
	C2,C23	0.104	0.056	C2,C22	0.159	0.207
	C3,C23	-0.258	-0.342	C3,C22	***0.542***	***0.571***
	C28,C23	-0.373	***-0.560***	C28,C22	0.210	0.145
	C1,C14	0.019	-0.042	C1,C15	0.021	-0.035
	C2,C14	0.220	0.115	C2,C15	-0.133	-0.237
	C3,C14	***0.500***	***0.524***	C3,C15	***-0.601***	***-0.544***
Nipple	C28,C14	0.330	0.311	C28,C15	-0.187	-0.183
	C1,C26	***-0.454***	-0.211	C1,C25	0.147	0.035
	C2,C26	-0.099	-0.068	C2,C25	0.137	0.118
	C3,C26	***-0.514***	***-0.486***	C3,C25	***0.618***	***0.646***
	C28,C26	-0.406	-0.198	C28,C25	0.272	0.247

Legend	C1	Age
	C2	Bust size
	C3	Cup size
	C28	Ptosis
	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 6.3 The correlation coefficients of age, bust size, cup size and ptosis in relation to posture distortion

		Medial Measurement	Lateral Measurement		Medial Measurement	Lateral Measurement
Outer	C5,C17	***-0.540***	***-0.832***	C6,C16	***-0.723***	***-0.932***
Upper	C8,C20	0.205	***-0.587***	C9,C19	***-0.561***	***-0.817***
Inner	C11,C23	-0.309	-0.406	C12,C22	***-0.719***	***-0.607***
Nipple	C14,C26	-0.393	-0.250	C15,C25	***-0.712***	***-0.811***

Legend	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 6.4 The correlation coefficients of arm movements in relation to posture distortion

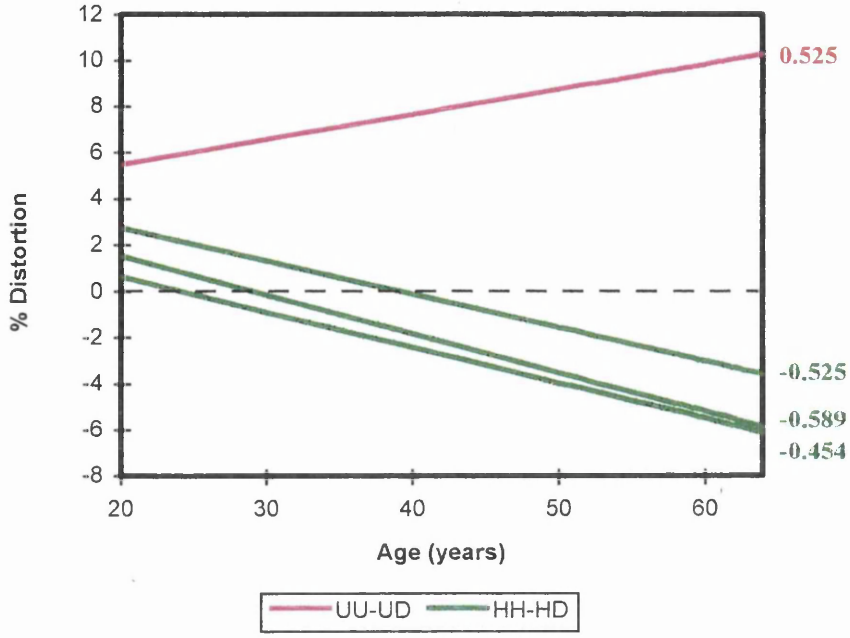


Figure 6.1 **Correlation of age and posture distortion**

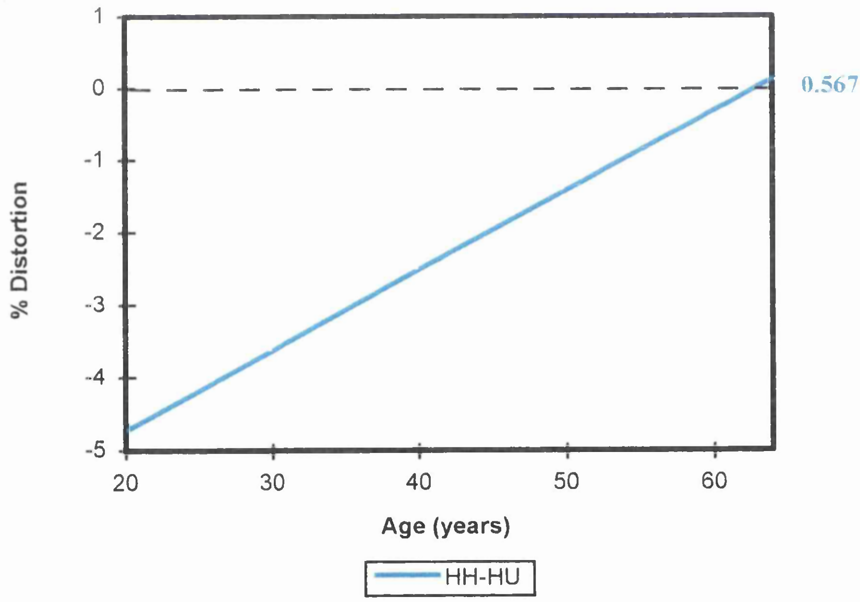


Figure 6.2 **Correlation of age and posture distortion**

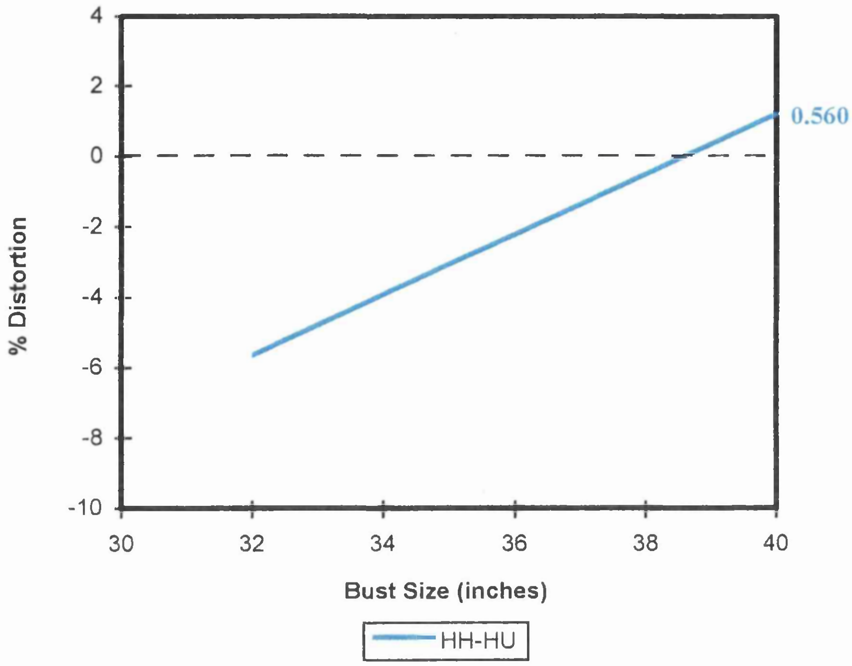


Figure 6.3 **Correlation of bust size and posture distortion**

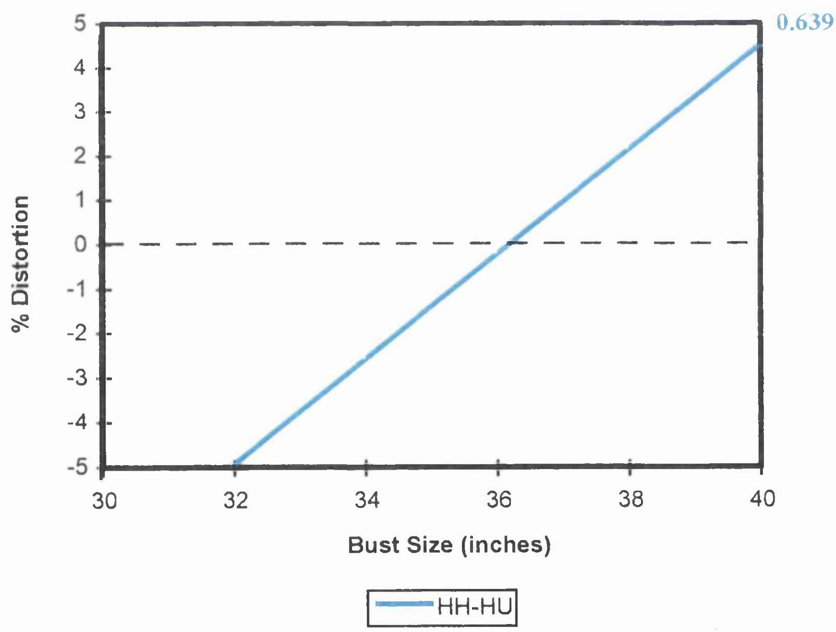


Figure 6.4 **Correlation of bust size and posture distortion**

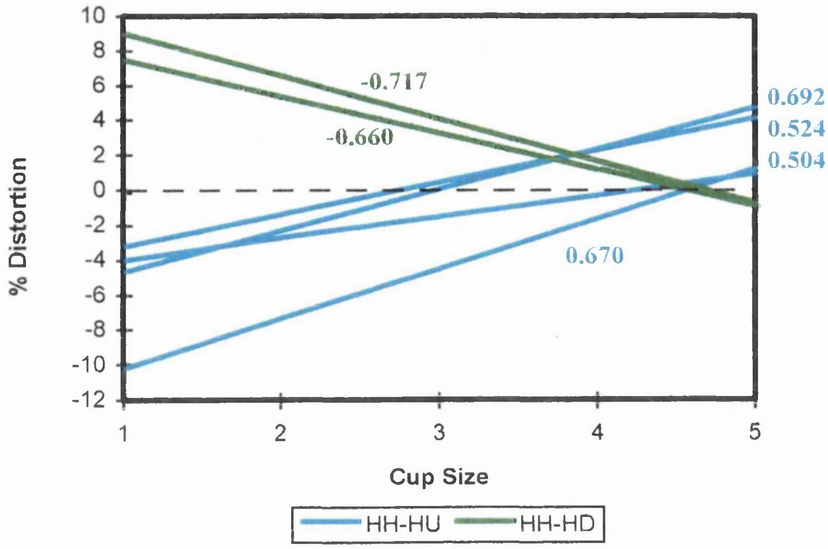


Figure 6.5 Correlation of cup size and posture distortion

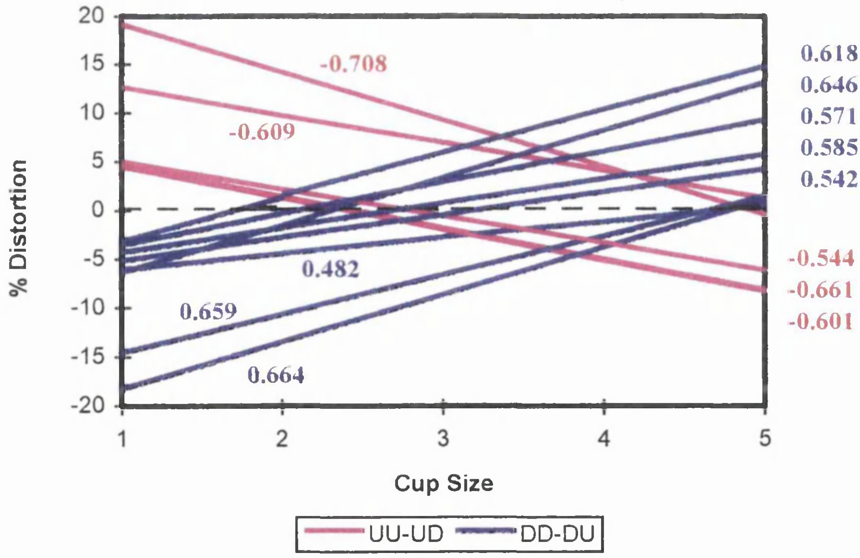


Figure 6.6 Correlation of cup size and posture distortion

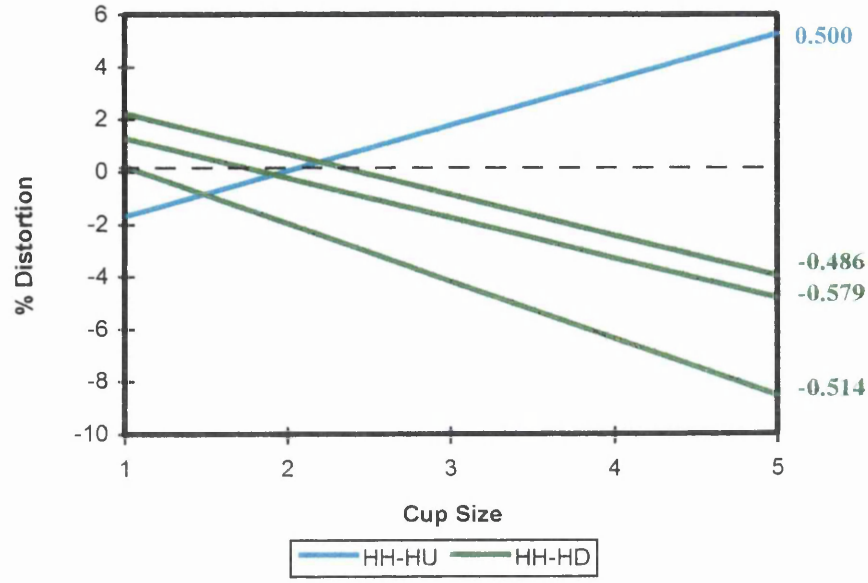


Figure 6.7 Correlation of cup size and posture distortion

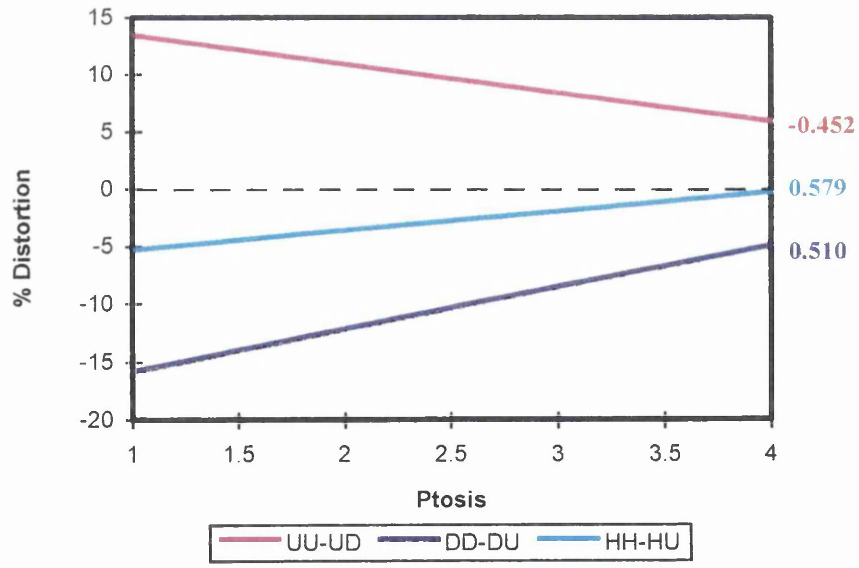


Figure 6.8 Correlation of ptosis index and posture distortion

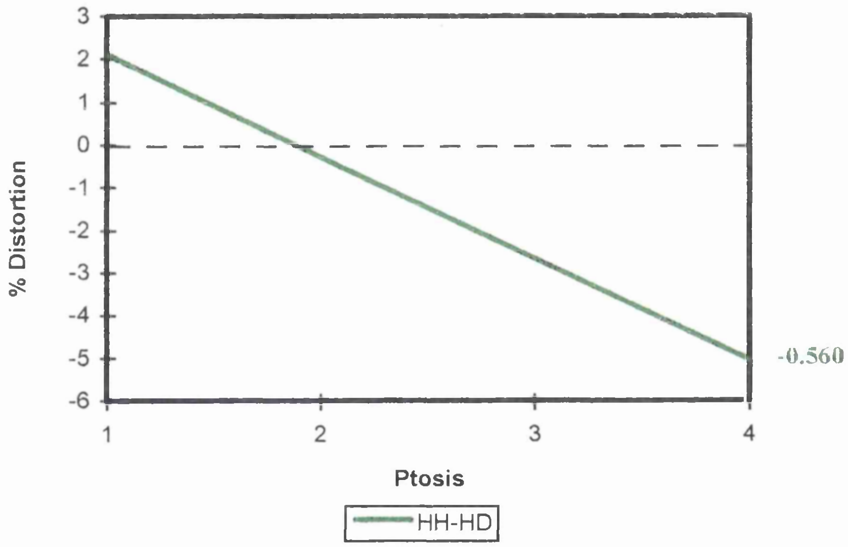


Figure 6.9 Correlation of ptosis index and posture distortion

Chapter 7

ANALYSIS OF THE DIAGONAL MEASUREMENTS

Chapter 7

ANALYSIS OF THE DIAGONAL MEASUREMENTS

7.1 INTRODUCTION

The main study of posture distortion in the female breast produced six measurement tables of data from the left breast. The analysis of the measurement tables of the two diagonal measurements commenced by studying the minimum and maximum posture distortion percentage values. The significance of age, bust size, cup size, ptosis and arm movement in relation to posture distortion in the diagonal axes were also assessed.

7.2 MATERIALS AND METHODS

The upper medial to lower lateral diagonal of the die stamp was represented by the diagonal measurement 12. The upper lateral to lower medial diagonal of the die stamp was represented by the diagonal measurement 15. This enabled comparisons to be made between the diagonal measurements which were originally perpendicular to one another.

The analysis of the diagonal measurement tables commenced by using Minitab to describe the values in C4-C27 as shown previously in Tables 4.10 and 4.11. The values selected were the minimum and maximum posture distortion percentage values. Posture distortion occurred as expansion and contraction with respect to change in the study marks due to arm movement.

The analysis focused on the arm movements which were considered to be most relevant to bite mark cases, these being horizontal to up, horizontal to down, up to down and down to up.

The relationships between the age, bust size, cup size, ptosis index and the posture distortion percentage values were examined using linear correlation tests within Minitab. Utilising Pearson's correlation coefficient (Altman, 1991) for a sample size of 20, a correlation of $> + 0.4438$ or $< - 0.4438$ is significant at the 5% level. The correlation coefficients which were assessed as statistically significant were plotted as graphs which demonstrated the relationship between the age, bust size, cup size, ptosis index and the posture distortion percentage values.

7.3 RESULTS

7.3.1 Minimum and maximum posture distortion percentage values

The minimum and maximum posture distortion percentage values of the two diagonal measurements in each of the four breast sites are shown in Table 7.1. The data illustrated the range of posture distortion exhibited by the 20 subjects. The upper medial to lower lateral and upper lateral to lower medial diagonal measurements demonstrated a varied pattern of distortion in each of the four sites. The minimum and maximum distortion values of the two diagonal measurements varied in each of the four sites. The upper medial to lower lateral measurement demonstrated higher distortion values than the upper lateral to lower medial measurement in the four sites. In general terms, arm movement downwards produced expansion of the upper medial to lower lateral measurement in the four sites; by contrast, arm movement upwards produced contraction of the upper medial to lower lateral measurement in the four sites. Arm movements downwards and upwards each produced expansion and contraction of the upper lateral to lower medial measurement in the four sites.

7.3.2. Posture distortion in relation to site

The maximum values of expansion and contraction of the two diagonal measurements in the four breast sites are shown in Table 7.2. The maximum distortion values of the upper medial to lower lateral measurement in the four sites were produced by the most extensive arm movements. The maximum distortion values of the upper lateral to lower medial measurement in the upper, inner and nipple sites were produced by the most extensive arm movements and in the outer site by a variety of arm movements. The maximum expansion values of the two diagonal measurements varied in the outer, upper and nipple sites and were comparable in the inner site. The maximum contraction values of the two diagonal measurements varied in the outer, upper and nipple sites and were comparable in the inner site. The findings corresponded with the minimum and maximum distortion values in the outer, upper and nipple sites and not in the inner site.

The maximum expansion and contraction values of the upper medial to lower lateral measurement were similar in the outer and inner sites. The values ranged from 14.20% to 21.36%. The maximum expansion and contraction values of the upper medial to lower lateral measurement were similar in the upper and nipple sites. The values ranged from 23.32% to 31.55%. The maximum expansion and contraction values of the upper lateral to lower medial measurement were comparable in the outer site, the range being from 5.10% to 6.01%. The maximum expansion and contraction values of the diagonal measurements were similar in the inner site. The values ranged from 9.12% to 15.07%. The maximum expansion and contraction values of the upper medial to lower lateral measurement were higher than the corresponding values of the upper lateral to lower medial measurement in the outer, upper and nipple sites. The maximum distortion values were demonstrated by the upper medial to lower lateral measurement in the upper and nipple sites.

7.3.3 Posture distortion in relation to age, bust size, cup size and ptosis

The correlation coefficients of the age, bust size, cup size and ptosis index in relation to posture distortion in each of the four breast sites are shown in Table 7.3. The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface.

Age was significantly correlated with distortion in the upper, inner and nipple sites. Age appeared to have a greater influence in the upper and nipple sites. Significant correlations of age with distortion occurred in the upper site with distortion of the upper medial to lower lateral measurement produced by the least extensive arm movements, horizontal to up and horizontal to down. In addition, the most extensive arm movement, up to down, showed significant correlations of age with distortion of the diagonal measurements. In the inner site, a significant correlation was found with the least extensive arm movement, horizontal to down, for the distortion of the upper lateral to lower medial measurement. At the nipple site, a significant correlation of age with distortion was noted in the upper medial to lower lateral measurement produced by the least extensive arm movement, horizontal to down. In addition, significant correlations of age with distortion occurred in the upper medial to lower lateral measurement due to the most extensive arm movements, up to down and down to up. The significant correlations of age with distortion of the diagonal measurements were produced equally by the least and most extensive arm movements.

Bust size was significantly correlated with distortion only in the inner site. Significant correlations of bust size with distortion were noted in the upper lateral to lower medial measurement due to the least and most extensive arm movements, horizontal to up and up to down. Consequently, the significant correlations of bust size with distortion of the upper lateral to lower medial measurement were produced equally by the least and most extensive arm movements.

Cup size was significantly correlated with distortion in the four sites. Cup size appeared to have a greater influence in the inner and nipple sites. In the outer site, a significant correlation was found with the least extensive arm movement, horizontal to up, for the distortion of the upper medial to lower lateral measurement. The most extensive arm movement, up to down, also showed a significant correlation of cup size with distortion of the upper lateral to lower medial measurement. In addition, a significant correlation of cup size with distortion occurred in the upper medial to lower lateral measurement due to the most extensive arm movement, down to up. In the upper site, significant correlations were noted with the least and most extensive arm movements, horizontal to down and down to up, for the distortion of the upper medial to lower lateral measurement. In the inner site, a significant correlation of cup size with distortion was found in the upper medial to lower lateral measurement produced by the least extensive arm movement, horizontal to up. The most extensive arm movement, up to down, also showed a significant correlation of cup size with distortion of the diagonal measurements. In addition, a significant correlation of cup size with distortion occurred in the upper lateral to lower medial measurement due to the most extensive arm movement, down to up. At the nipple site, a significant correlation was noted with the least extensive arm movement, horizontal to up, for the distortion of the upper lateral to lower medial measurement. The most extensive arm movements, up to down and down to up, also showed significant correlations of cup size with distortion of the diagonal measurements. The significant correlations of cup size with distortion of the diagonal measurements were produced mainly by the most extensive arm movements.

The ptosis index was significantly correlated with distortion in the four sites. Significant correlations of ptosis with distortion were found in the outer site with distortion of the upper medial to lower lateral measurement due to the least and most extensive arm movements, horizontal to up and down to up. Similarly, in the upper site, significant correlations of ptosis with distortion occurred in the upper medial to lower lateral measurement produced by the least and most extensive arm movements, horizontal to down and up to down. In the inner site, a significant correlation of ptosis with distortion was noted in the upper lateral to lower medial measurement due to the least extensive arm movement, horizontal to down. At the nipple site, the ptosis index appeared to have a greater influence. A significant correlation of ptosis with distortion was found in the upper medial to lower lateral measurement due to the least extensive arm movement, horizontal to up. The most extensive arm movements, up to down and down to up, also showed significant correlations of ptosis with distortion of the upper medial to lower lateral measurement. The significant correlations of ptosis with distortion of the diagonal measurements were produced equally by the least and most extensive arm movements. The statistical correlations of age with distortion and ptosis with distortion were comparable in the upper, inner and nipple sites and not in the outer site.

7.3.4 Posture distortion in relation to arm movement

The correlation coefficients of the arm movement in relation to posture distortion in each of the four breast sites are shown in Table 7.4. The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface. The arm movements horizontal to up and horizontal to down were significantly correlated with distortion of the upper lateral to lower medial measurement in the upper site. The arm movements up to down and down to up were significantly correlated with distortion of the diagonal measurements in the upper, inner and nipple sites. The significant correlations of arm movement with distortion of the diagonal measurements were produced by the most extensive arm movements, with one exception.

7.3.5 Significant correlations

The significance of the age, bust size, cup size and ptosis index were demonstrated by plotting the statistically significant correlation coefficients of the subjects' data and the posture distortion percentage values as graphs. The statistically significant correlation coefficients are highlighted in bold italicised typeface in Tables 7.3 and 7.4.

Age and the posture distortion percentage values were positively correlated with the arm movements down to up and horizontal to up and inversely correlated with the arm movements up to down and horizontal to down. An increase in age was related to an increase in the magnitude of distortion produced by the arm movements up to down, down to up, horizontal to up and horizontal to down (Figure 7.1); one of the graphs of the arm movement horizontal to down also demonstrated a decrease in the magnitude of distortion associated with an increase in age of younger subjects (Table 4.11 C23). An increase in age of younger subjects was related to a decrease in the magnitude of distortion produced by the arm movement up to down; an increase in age of older subjects was related to an increase in the magnitude of distortion produced by the arm movement up to down (Figure 7.2; Table 4.11 C9).

Bust size and the posture distortion percentage values were positively correlated with the arm movement horizontal to up and inversely correlated with the arm movement up to down. An increase in bust size was related to a decrease in the magnitude of distortion produced by the arm movements up to down and horizontal to up (Figure 7.3); the graphs also demonstrated an increase in the magnitude of distortion associated with larger bust sizes (Table 4.11 C11, C12).

Cup size and the posture distortion percentage values were positively correlated with the arm movements up to down, down to up and horizontal to up and inversely correlated with the arm movements up to down, horizontal to up and horizontal to down. An increase in cup size was related to an increase in the magnitude of distortion produced by the arm movements up to down, down to up, horizontal to up and horizontal to down (Figure 7.4). An increase in cup size was related to a decrease in the magnitude of distortion produced by the arm movement up to down (Figure 7.5). An increase in smaller cup sizes was related to a decrease in the magnitude of distortion produced by the arm movements up to down, down to up and horizontal to up (Figure 7.5); the graphs also demonstrated an increase in the magnitude of distortion associated with larger cup sizes (Table 4.10 C11; Table 4.11 C12, C14, C22, C25).

Ptosis and the posture distortion percentage values were positively correlated with the arm movements down to up and horizontal to up and inversely correlated with the arm movements up to down and horizontal to down. An increase in the ptosis index was related to an increase in the magnitude of distortion produced by the arm movements up to down, down to up, horizontal to up and horizontal to down (Figure 7.6); one of the graphs of the arm movement horizontal to down also demonstrated a decrease in the magnitude of distortion associated with smaller ptosis indices (Table 4.11 C23).

7.4 DISCUSSION

Posture distortion was produced by arm movement in a selected plane, namely, vertically by the subject's side. The selected plane has a specific anatomical relationship with the diagonal axes in each of the four breast sites. Consequently, the posture distortion values were related to two specific anatomical relationships in each site. The extent and direction of arm movement, within the selected plane, were subject to variation. In this way, the influence of arm movement was assessed.

The minimum and maximum distortion values of the two diagonal measurements varied in each of the four sites. Therefore, distortion in the two diagonal axes within the study marks was variable in each of the four breast sites. The upper medial to lower lateral measurement demonstrated higher distortion values than the upper lateral to lower medial measurement in the four sites. Arm movement in opposite directions produced comparable expansion and contraction values of the upper lateral to lower medial measurement in the four sites. In effect, alternating the direction of arm movement produced a mirror image of expansion and contraction in the four sites. Arm movement in opposite directions produced less comparable expansion and contraction values of the upper medial to lower lateral measurement in the four sites.

The minimum and maximum distortion values of the two diagonal measurements varied in each of the four sites. The variation in distortion between the diagonal measurements was consistent with the fact that the two diagonal axes were originally perpendicular to one another. The minimum and maximum distortion values demonstrated that, in general terms, arm movement downwards produced expansion of the upper medial to lower lateral measurement in the four sites; by contrast, arm movement upwards produced contraction of the upper medial to lower lateral measurement in the four sites. Arm movements downwards and upwards each produced expansion and contraction of the upper lateral to lower medial measurement in the four sites.

The maximum expansion and contraction values of the upper medial to lower lateral measurement in the four sites were produced by the most extensive arm movements. It was thought that the upper medial to lower lateral measurement underwent distortion in the four sites in proportion to arm movement. The maximum expansion and contraction values of the upper lateral to lower medial measurement in the upper, inner and nipple sites were produced by the most extensive arm movements and in the outer site by a variety of arm movements. It was thought that the upper lateral to lower medial measurement underwent distortion in the upper, inner and nipple sites in proportion to arm movement and in the outer site in a complex relationship to arm movement.

The significant correlations of age with distortion of the diagonal measurements were produced equally by the least and most extensive arm movements. The significant correlations of bust size with distortion of the upper lateral to lower medial measurement were produced equally by the least and most extensive arm movements. The significant correlations of cup size with distortion of the diagonal measurements were produced mainly by the most extensive arm movements. The significant correlations of ptosis with distortion of the diagonal measurements were produced equally by the least and most extensive arm movements. The significant correlations of arm movement with distortion of the diagonal measurements were produced by the most extensive arm movements, with one exception. In view of these findings, it was considered that the significance, in the diagonal axes, of the least and most extensive arm movements, was related to the selected plane of arm movement.

The initial stages of the main study (Chapter 4) demonstrated that age and ptosis were positively correlated; an increase in age was related to an increase in ptosis. This is consistent with the findings that the statistical correlations of age with distortion and ptosis with distortion were comparable in the diagonal axes in three of four possible breast sites.

7.5 CONCLUSIONS

Distortion in the upper medial to lower lateral diagonal axis was greater than the upper lateral to lower medial diagonal axis in the four sites. Therefore, distortion in the two diagonal axes was variable in each of the four breast sites. In general terms, the upper medial to lower lateral diagonal axis in the four breast sites expanded in response to arm movement downwards and contracted in response to arm movement upwards. The upper lateral to lower medial diagonal axis in the four breast sites expanded and contracted in response to arm movements downwards and upwards. The upper medial to lower lateral diagonal axis in the upper and nipple sites underwent maximum distortion of 31.55% and 30.96% respectively in response to the most extensive arm movement, up to down. The upper medial to lower lateral diagonal axis in the outer and inner sites underwent maximum distortion of 21.36% and 15.07% respectively in response to the most extensive arm movements, down to up and up to down.

The clinical significance of age was contradictory - an increase in the subjects' age was related to an increase and a decrease in the magnitude of distortion in the two diagonal axes in the upper, inner and nipple sites. The clinical significance of ptosis was that an increase in the ptosis index was predominantly related to an increase in the magnitude of distortion in the two diagonal axes in the four breast sites. The clinical significance of bust size was contradictory - an increase in the subjects' bust size was related to an increase and a decrease in the magnitude of distortion in the two diagonal axes in the inner site. The clinical significance of cup size was contradictory - an increase in the subjects' cup size was related to an increase and a decrease in the magnitude of distortion in the two diagonal axes in the four breast sites. The clinical significance of arm movement was that the least and most extensive arm movements were significant in the two diagonal axes in the upper site and only the most extensive arm movements were significant in the two diagonal axes in the inner and nipple sites.

Arm Movement		Upper medial to lower lateral measurement Minimum	Maximum	Upper lateral to lower medial measurement Minimum	Maximum
	DD-DH	0.25	10.85	3.73	-5.56
Outer	HH-HU	-2.06	8.04	-3.18	3.52
	UU-UD	-0.31	-15.82	2.80	-5.45
	DD-DH	-0.51	12.96	-0.07	-12.35
Upper	HH-HU	3.28	16.77	-1.12	-9.53
	UU-UD	-6.82	-31.55	-9.48	13.63
	DD-DH	-1.47	9.79	-4.77	5.15
Inner	HH-HU	-8.82	9.19	1.11	-12.62
	UU-UD	4.59	-15.07	-2.67	9.12
	DD-DH	-0.86	17.13	4.75	-6.58
Nipple	HH-HU	-0.08	14.44	4.14	-7.02
	UU-UD	-6.75	-30.96	5.21	-12.88
	DD-DU	-2.68	21.36	5.10	-6.01
Outer	HH-HD	0.30	-11.31	-3.68	4.26
	UU-UH	1.81	-9.32	4.39	-4.95
	DD-DU	4.70	23.32	1.55	-24.15
Upper	HH-HD	-2.12	-14.74	-2.23	9.51
	UU-UH	-3.02	-17.20	-4.01	7.16
	DD-DU	4.29	14.20	5.75	-14.58
Inner	HH-HD	-1.12	-9.73	4.65	-7.89
	UU-UH	-1.64	-12.64	-3.35	6.52
	DD-DU	5.67	28.79	5.21	-13.92
Nipple	HH-HD	-1.33	-20.83	6.63	-9.90
	UU-UH	0.12	-17.38	5.54	-12.04

Table 7.1 The minimum and maximum posture distortion percentage values of the diagonal measurements

Site	Expansion		Contraction	
Outer	***15.82***	6.01	***21.36***	5.10
Upper	***31.55***	24.15	***23.32***	13.63
Inner	***15.07***	14.58	***14.20***	9.12
Nipple	***30.96***	13.92	***28.79***	*6.63*

Table 7.2 The maximum posture distortion percentage values of the diagonal measurements (upper medial to lower lateral measurement in italics)

		Upper medial to lower lateral measurement	Upper lateral to lower medial measurement		Upper medial to lower lateral measurement	Upper lateral to lower medial measurement
	C1,C5	0.410	-0.136	C1,C6	-0.312	-0.291
	C2,C5	0.205	0.205	C2,C6	-0.005	0.003
	C3,C5	***0.816***	0.178	C3,C6	-0.241	***-0.559***
Outer	C28,C5	***0.539***	-0.185	C28,C6	-0.088	-0.213
	C1,C17	-0.313	0.100	C1,C16	0.374	0.036
	C2,C17	0.025	0.313	C2,C16	-0.059	0.126
	C3,C17	-0.302	0.166	C3,C16	***0.530***	0.371
	C28,C17	-0.217	0.170	C28,C16	***0.450***	0.030
	C1,C8	***0.547***	0.037	C1,C9	***-0.740***	***-0.466***
	C2,C8	0.045	0.226	C2,C9	-0.285	-0.310
	C3,C8	0.131	0.176	C3,C9	-0.420	-0.357
Upper	C28,C8	0.375	0.064	C28,C9	***-0.624***	-0.402
	C1,C20	***-0.507***	-0.071	C1,C19	0.411	-0.052
	C2,C20	-0.236	-0.094	C2,C19	-0.114	0.307
	C3,C20	***-0.576***	-0.215	C3,C19	***0.476***	0.232
	C28,C20	***-0.440***	-0.087	C28,C19	0.351	0.186
	C1,C11	0.215	0.168	C1,C12	-0.318	-0.250
	C2,C11	-0.135	***0.669***	C2,C12	0.060	***-0.498***
	C3,C11	***-0.738***	0.389	C3,C12	***0.486***	***-0.519***
Inner	C28,C11	0.119	0.289	C28,C12	-0.178	-0.329
	C1,C23	-0.320	***-0.524***	C1,C22	0.276	0.040
	C2,C23	-0.021	0.095	C2,C22	-0.139	0.408
	C3,C23	-0.192	-0.353	C3,C22	-0.186	***0.780***
	C28,C23	-0.071	***-0.498***	C28,C22	0.034	0.122
	C1,C14	0.354	-0.178	C1,C15	***-0.636***	-0.377
	C2,C14	0.230	0.149	C2,C15	-0.268	-0.318
	C3,C14	0.213	***0.496***	C3,C15	***-0.556***	***-0.525***
Nipple	C28,C14	***0.474***	0.193	C28,C15	***-0.564***	-0.431
	C1,C26	***-0.484***	-0.149	C1,C25	***0.582***	-0.092
	C2,C26	0.086	-0.144	C2,C25	0.136	0.284
	C3,C26	-0.309	-0.264	C3,C25	***0.567***	***0.583***
	C28,C26	-0.404	-0.093	C28,C25	***0.539***	0.100

Legend		
	C1	Age
	C2	Bust size
	C3	Cup size
	C28	Ptosis
	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 7.3 The correlation coefficients of age, bust size, cup size and ptosis in relation to posture distortion

		Upper medial to lower lateral measurement	Upper lateral to lower medial measurement		Upper medial to lower lateral measurement	Upper lateral to lower medial measurement
Outer	C5,C17	-0.309	0.279	C6,C16	-0.386	-0.335
Upper	C8,C20	-0.240	***-0.439***	C9,C19	***-0.728***	***-0.635***
Inner	C11,C23	0.048	-0.178	C12,C22	***-0.554***	***-0.680***
Nipple	C14,C26	0.263	0.163	C15,C25	***-0.688***	***-0.534***

Legend	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 7.4 The correlation coefficients of arm movement in relation to posture distortion

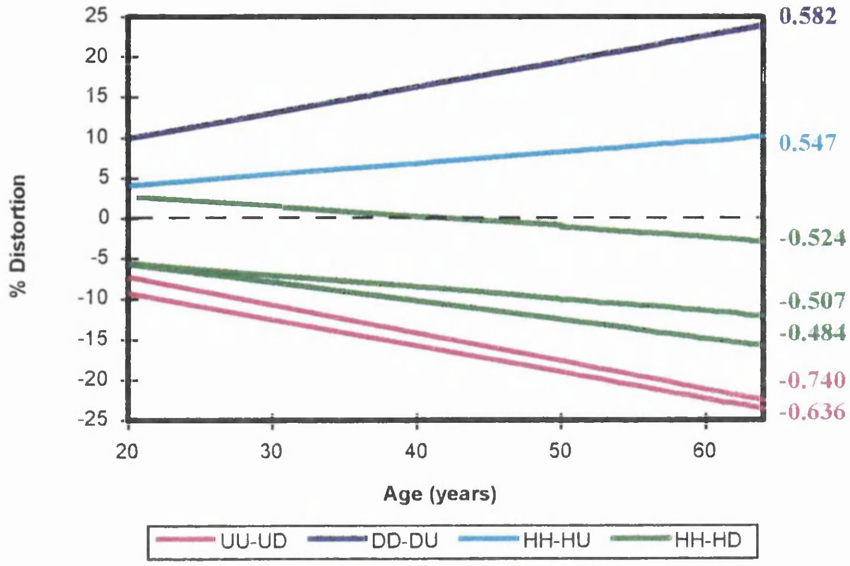


Figure 7.1 **Correlation of age and posture distortion**

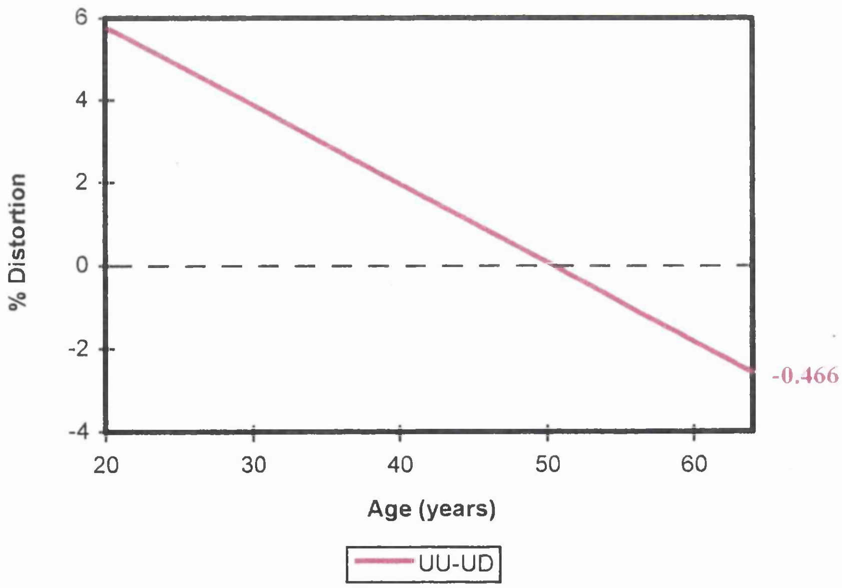


Figure 7.2 **Correlation of age and posture distortion**

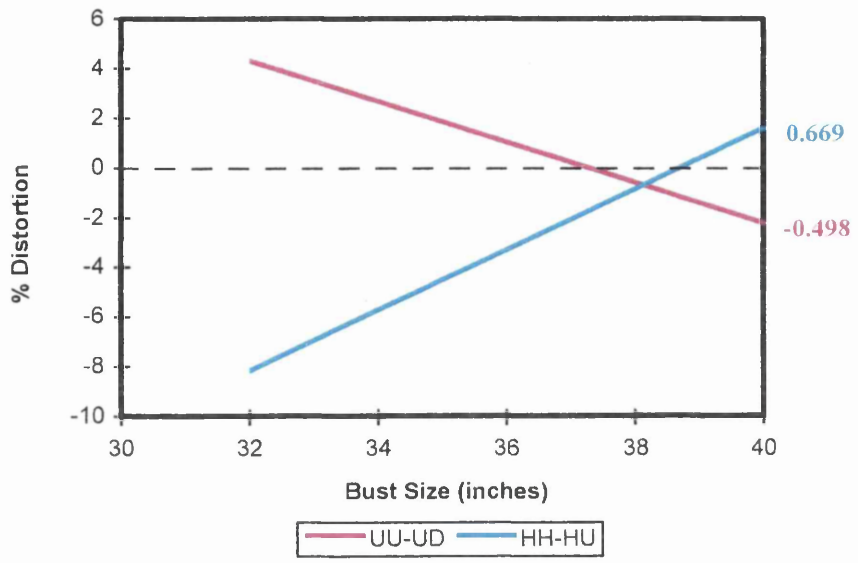


Figure 7.3 Correlation of bust size and posture distortion

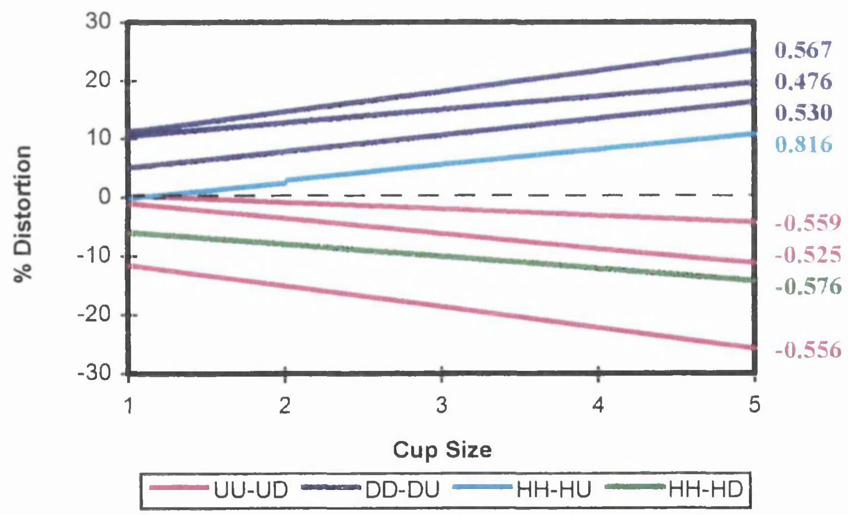


Figure 7.4 Correlation of cup size and posture distortion

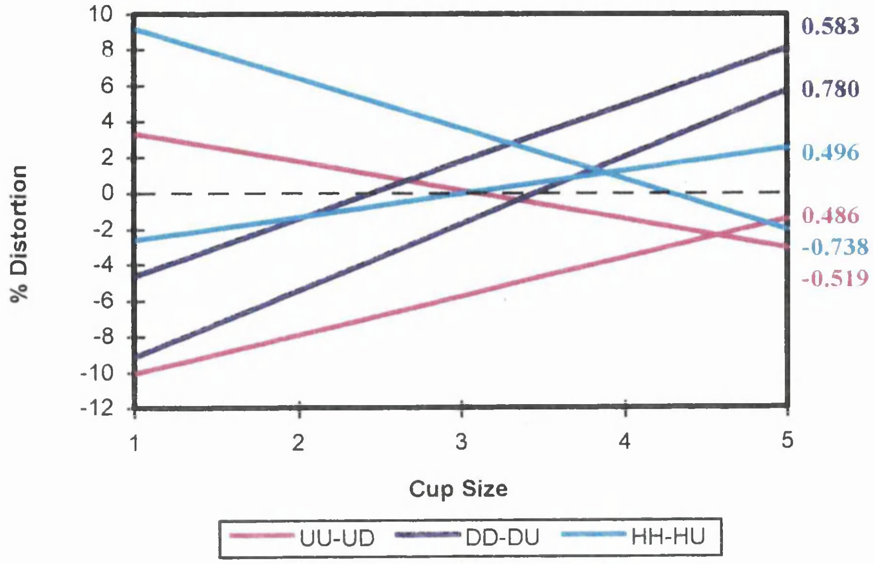


Figure 7.5 Correlation of cup size and posture distortion

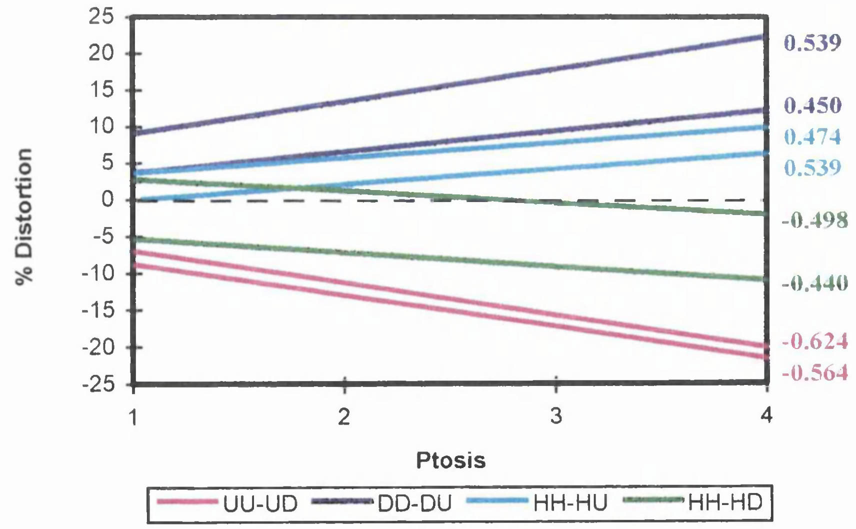


Figure 7.6 Correlation of ptosis index and posture distortion

Chapter 8

COMPARATIVE ANALYSIS OF THE HORIZONTAL, VERTICAL AND DIAGONAL MEASUREMENTS

Chapter 8

COMPARATIVE ANALYSIS OF THE HORIZONTAL, VERTICAL AND DIAGONAL MEASUREMENTS

8.1 INTRODUCTION

The main study of posture distortion in the female breast produced six measurement tables of data from the left breast. The analysis of the measurement tables was continued by comparing the four axes in each of the four breast sites.

8.2 MATERIALS AND METHODS

The die stamp was a 34 mm square. Therefore, the horizontal measurements and the vertical measurements were originally parallel and 34 mm apart; the diagonal measurements were originally perpendicular to one another. Consequently, the analysis of the horizontal measurements and of the vertical measurements was a study of originally comparable axes; by contrast, the analysis of the diagonal measurements was a study of originally opposed axes.

The comparative analysis of the six measurement tables commenced by tabulating the maximum posture distortion percentage values of the six measurements.

The correlation coefficients of the age, bust size, cup size and ptosis index in relation to posture distortion in each of the four breast sites were tabulated. The posture distortion produced by the least and most extensive arm movements were cast into separate tables.

8.3 RESULTS

8.3.1 Maximum posture distortion percentage values

The maximum values of expansion and contraction of the six measurements in each of the four breast sites are shown in Tables 8.1 and 8.2 respectively. In general terms, the horizontal measurements demonstrated the highest maximum distortion values in the four sites; the inner site demonstrated the lowest maximum distortion values of the six measurements in the four axes.

8.3.2 Posture distortion in relation to age, bust size, cup size and ptosis

The correlation coefficients of the age, bust size, cup size and ptosis index in relation to posture distortion produced by the least and most extensive arm movements in each of the four breast sites are shown in Tables 8.3 and 8.4 respectively. The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface.

The posture distortion produced by the least extensive arm movements was most significant in the vertical axis, was less significant in the diagonal axes and had minimum significance in the horizontal axis. Cup size appeared to have the greatest influence; age and ptosis showed less influence and bust size had least influence.

The posture distortion produced by the most extensive arm movements was significant in the four axes. Cup size appeared to have the greatest influence; age and ptosis showed less influence and bust size had almost no influence.

8.3.3 Posture distortion in relation to arm movement

The correlation coefficients of the arm movement in relation to posture distortion produced by the least and most extensive arm movements in each of the four breast sites are shown in Tables 8.5 and 8.6 respectively. The correlation coefficients consist of positive correlations and inverse correlations which are indicated by positive and negative values respectively. The statistically significant correlation coefficients are highlighted in bold italicised typeface.

The least extensive arm movements demonstrated four statistically significant correlation coefficients from a total of 24 correlation coefficients. The most extensive arm movements demonstrated 19 statistically significant correlation coefficients from a total of 24 correlation coefficients.

8.4 DISCUSSION

Posture distortion was produced by arm movement in a selected plane, namely, vertically by the subject's side. The selected plane has a specific anatomical relationship with the horizontal, vertical and diagonal axes in each of the four breast sites. Consequently, the posture distortion values were related to four specific anatomical relationships in each site. Posture distortion produced by arm movement in alternative body planes would require further research.

The horizontal measurements were originally parallel, 34 mm apart and therefore comparable. Distortion in the horizontal axis was relatively uniform in each of the four breast sites. This finding indicated that the specific anatomical relationship involving the horizontal axis was consistent in each site.

The vertical measurements were originally parallel, 34 mm apart and therefore comparable. Distortion in the vertical axis was variable in the outer and upper sites and was relatively uniform in the inner and nipple sites. This finding indicated that the specific anatomical relationship involving the vertical axis was site dependent.

The diagonal measurements were originally perpendicular to one another and therefore opposed. Distortion in the two diagonal axes was variable in each of the four breast sites. This finding was consistent with the specific anatomical relationship involving two opposing diagonal axes in each site.

8.5 CONCLUSIONS

In general terms, maximum distortion occurred in the horizontal axis in the four breast sites. Therefore, the horizontal axis was the most susceptible to distortion. In general terms, maximum distortion was lowest in the inner site in the four axes. Therefore, the inner site was the least susceptible to distortion.

The subjects' age was often a statistically significant factor in the four axes. The clinical significance of age demonstrated minor variations in the four axes. An increase in age was mainly related to an increase in the magnitude of distortion. The subjects' bust size was rarely a statistically significant factor in the four axes. The clinical significance of bust size demonstrated minor variations in the vertical and diagonal axes. An increase in bust size was mainly related to a decrease in the magnitude of distortion. The subjects' cup size was the most frequent statistically significant factor in the four axes. The clinical significance of cup size demonstrated variations in the four axes. An increase in cup size was related to an increase and a decrease in the magnitude of distortion. The ptosis index was often a statistically significant factor in the four axes. The clinical significance of ptosis demonstrated variation in the vertical axis. An increase in ptosis was related to an increase in the magnitude of distortion in the four axes. However, an increase in ptosis was predominantly related to a decrease in the magnitude of distortion in the vertical axis.

The least and most extensive arm movements demonstrated a low and high frequency respectively of statistically significant correlation coefficients. Therefore, the contrast in the frequency of statistically significant correlation coefficients was related to the extent of arm movement in the four axes.

Posture distortion was related to the extent of arm movement and the four specific anatomical relationships in each breast site.

Measurement Site	Upper Horizontal	Lower Horizontal	Medial Vertical	Lateral Vertical	Upper medial to lower lateral diagonal	Upper lateral to lower medial diagonal
Outer	27.78	26.66	9.96	26.63	15.82	6.01
Upper	33.23	38.67	13.55	21.58	31.55	24.15
Inner	20.49	16.87	11.30	13.91	15.07	14.58
Nipple	37.21	37.95	14.87	18.03	30.96	13.92

Table 8.1. The maximum expansion values

Measurement Site	Upper Horizontal	Lower Horizontal	Medial Vertical	Lateral Vertical	Upper medial to lower lateral diagonal	Upper lateral to lower medial diagonal
Outer	25.47	24.50	10.46	25.23	21.36	5.10
Upper	20.68	21.01	13.12	19.23	23.32	13.63
Inner	14.91	14.19	8.46	11.79	14.20	9.12
Nipple	27.53	23.15	13.31	10.08	28.79	6.63

Table 8.2 The maximum contraction values

		Upper Horizontal	Lower Horizontal	Medial Vertical	Lateral Vertical	Upper medial to lower lateral diagonal	Upper lateral to lower medial diagonal
	C1,C5	0.331	0.157	0.041	0.100	0.410	-0.136
	C2,C5	0.213	-0.397	0.383	0.303	0.205	0.205
	C3,C5	0.248	-0.229	***0.692***	***0.670***	***0.816***	0.178
Outer	C28,C5	0.152	-0.069	0.327	0.303	***0.539***	-0.185
	C1,C17	-0.227	0.112	-0.195	-0.166	-0.313	0.100
	C2,C17	0.360	0.262	-0.069	-0.238	0.025	0.313
	C3,C17	0.307	0.428	***-0.579***	***-0.717***	-0.302	0.166
	C28,C17	-0.024	0.359	-0.199	-0.414	-0.217	0.170
	C1,C8	0.198	0.239	0.219	***0.567***	***0.547***	0.037
	C2,C8	0.023	0.046	0.267	0.186	0.045	0.226
	C3,C8	-0.141	0.202	0.059	***0.504***	0.131	0.176
Upper	C28,C8	-0.102	0.346	0.133	***0.579***	0.375	0.064
	C1,C20	-0.305	***-0.522***	0.214	-0.234	***-0.507***	-0.071
	C2,C20	-0.236	-0.142	0.044	-0.242	-0.236	-0.094
	C3,C20	-0.266	-0.335	-0.275	***-0.660***	***-0.576***	-0.215
	C28,C20	-0.140	-0.306	-0.209	-0.434	***-0.440***	-0.087
	C1,C11	0.146	0.283	0.343	0.109	0.215	0.168
	C2,C11	0.092	-0.155	***0.560***	***0.639***	-0.135	***0.669***
	C3,C11	***-0.563***	***-0.630***	0.327	0.294	***-0.738***	0.389
Inner	C28,C11	0.054	0.245	0.340	0.298	0.119	0.289
	C1,C23	-0.408	0.138	***-0.525***	***-0.589***	-0.320	***-0.524***
	C2,C23	-0.060	-0.004	0.104	0.056	-0.021	0.095
	C3,C23	-0.212	-0.079	-0.258	-0.342	-0.192	-0.353
	C28,C23	-0.351	0.359	-0.373	***-0.560***	-0.071	***-0.498***
	C1,C14	0.257	0.301	0.019	-0.042	0.354	-0.178
	C2,C14	0.247	0.137	0.220	0.115	0.230	0.149
	C3,C14	0.074	0.028	***0.500***	***0.524***	0.213	***0.496***
Nipple	C28,C14	0.299	0.414	0.330	0.311	***0.474***	0.193
	C1,C26	-0.307	-0.399	***-0.454***	-0.211	***-0.484***	-0.149
	C2,C26	0.058	0.038	-0.099	-0.068	0.086	-0.144
	C3,C26	-0.130	-0.133	***-0.514***	***-0.486***	-0.309	-0.264
	C28,C26	-0.228	-0.309	-0.406	-0.198	-0.404	-0.093

Legend		
	C1	Age
	C2	Bust size
	C3	Cup size
	C28	Ptosis
	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD

Table 8.3 The correlation coefficients of age, bust size, cup size and ptosis in relation to posture distortion produced by the arm movements horizontal to up and horizontal to down

		Upper Horizontal	Lower Horizontal	Medial Vertical	Lateral Vertical	Upper medial to lower lateral diagonal	Upper lateral to lower medial diagonal
	C1,C6	-0.413	-0.065	-0.072	-0.138	-0.312	-0.291
	C2,C6	0.071	0.352	-0.195	-0.343	-0.005	0.003
	C3,C6	0.011	***0.447***	***-0.661***	***-0.708***	-0.241	***-0.559***
Outer	C28,C6	-0.104	0.219	-0.194	-0.288	-0.088	-0.213
	C1,C16	***0.548***	0.033	0.235	0.134	0.374	0.036
	C2,C16	0.189	-0.401	-0.009	0.221	-0.059	0.126
	C3,C16	0.324	-0.296	***0.585***	***0.664***	***0.530***	0.371
	C28,C16	***0.474***	-0.012	0.271	0.317	***0.450***	0.030
	C1,C9	***-0.747***	***-0.824***	***0.525***	-0.186	***-0.740***	***-0.466***
	C2,C9	-0.331	-0.293	0.123	-0.228	-0.285	-0.310
	C3,C9	-0.232	-0.409	0.005	***-0.609***	-0.420	-0.357
Upper	C28,C9	-0.431	***-0.685***	0.176	***-0.452***	***-0.624***	-0.402
	C1,C19	0.257	0.168	-0.271	0.257	0.411	-0.052
	C2,C19	0.269	0.165	-0.080	0.075	-0.114	0.307
	C3,C19	-0.093	0.275	***0.482***	***0.659***	***0.476***	0.232
	C28,C19	0.072	0.280	0.116	***0.510***	0.351	0.186
	C1,C12	-0.406	-0.206	-0.262	-0.040	-0.318	-0.250
	C2,C12	0.033	0.085	-0.432	-0.254	0.060	***-0.498***
	C3,C12	0.330	***0.514***	-0.374	-0.381	***0.486***	***-0.519***
Inner	C28,C12	-0.175	-0.061	-0.249	-0.365	-0.178	-0.329
	C1,C22	0.068	-0.001	0.356	0.046	0.276	0.040
	C2,C22	0.306	-0.013	0.159	0.207	-0.139	0.408
	C3,C22	0.195	0.078	***0.542***	***0.571***	-0.186	***0.780***
	C28,C22	-0.024	0.006	0.210	0.145	0.034	0.122
	C1,C15	***-0.675***	***-0.742***	0.021	-0.035	***-0.636***	-0.377
	C2,C15	-0.309	-0.299	-0.133	-0.237	-0.268	-0.318
	C3,C15	***-0.453***	-0.304	***-0.601***	***-0.544***	***-0.556***	***-0.525***
Nipple	C28,C15	***-0.596***	***-0.595***	-0.187	-0.183	***-0.564***	-0.431
	C1,C25	0.409	***0.510***	0.147	0.035	***0.582***	-0.092
	C2,C25	0.303	0.197	0.137	0.118	0.136	0.284
	C3,C25	***0.498***	0.269	***0.618***	***0.646***	***0.567***	***0.583***
	C28,C25	0.373	0.394	0.272	0.247	***0.539***	0.100

Legend	C1	Age
	C2	Bust size
	C3	Cup size
	C28	Ptosis
	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 8.4 **The correlation coefficients of age, bust size, cup size and ptosis in relation to posture distortion produced by the arm movements up to down and down to up.**

		Upper Horizontal	Lower Horizontal	Medial Vertical	Lateral Vertical	Upper medial to lower lateral diagonal	Upper lateral to lower medial diagonal
Outer	C5,C17	0.186	-0.287	***-0.540***	***-0.832***	-0.309	0.279
Upper	C8,C20	-0.200	0.182	0.205	***-0.587***	-0.240	***-0.439***
Inner	C11,C23	-0.115	0.278	-0.309	-0.406	0.048	-0.178
Nipple	C14,C26	0.295	0.426	-0.393	-0.250	0.263	0.163

Legend	C5, C8, C11, C14	HH-HU
	C17, C20, C23, C26	HH-HD

Table 8.5 **The correlation coefficients of arm movement in relation to posture distortion produced by the arm movements horizontal to up and horizontal to down**

		Upper Horizontal	Lower Horizontal	Medial Vertical	Lateral Vertical	Upper medial to lower lateral diagonal	Upper lateral to lower medial diagonal
Outer	C6,C16	***-0.468***	***-0.775***	***-0.723***	***-0.932***	-0.386	-0.335
Upper	C9,C19	***-0.447***	-0.333	***-0.561***	***-0.817***	***-0.728***	***-0.635***
Inner	C12,C22	-0.100	-0.317	***-0.719***	***-0.607***	***-0.554***	***-0.680***
Nipple	C15,C25	***-0.446***	***-0.446***	***-0.712***	***-0.811***	***-0.688***	***-0.534***

Legend	C6, C9, C12, C15	UU-UD
	C16, C19, C22, C25	DD-DU

Table 8.6 **The correlation coefficients of arm movement in relation to posture distortion produced by the arm movements up to down and down to up**

Chapter 9

DISCUSSION

Chapter 9

DISCUSSION

9.1 BITE MARK ANALYSIS - THE PROBLEMS

A bite mark in skin is evidence of contact between the teeth, either alone or in combination with other mouth parts, and the skin. Consequently, a bite mark is produced by three contributory components - dentition/mouth parts, skin and the episode of contact.

Skin is said to be a poor impression medium because it is not dimensionally stable and is not capable of reproducing detail. It is hypothesised that every episode of contact between the dentition/mouth parts and the skin is a unique event and therefore every bite mark is unique for a particular episode of contact. This hypothesis raises another theoretical statistical possibility, that different dentitions could produce identical marks. The combination of the nature of skin and the potential uniqueness of every episode of contact, produces a marked variation in the quality of bite marks and the possibility that similar bite marks may have different causal dentitions. The variations in the quality of bite marks and in the mechanism of bite mark production determine the complex nature of bite mark analysis.

The interpretation of the representation of the uniqueness of a dentition in a bite mark is the focal point of bite mark analysis. Bite mark analyis is the comparison of two pieces of evidence, namely the photographic record of the bite mark and the dental casts. The comparison consists of observing and interpreting points of comparability and incompatibility. The forensic dentist attempts to determine the points of comparability in an effort to enhance the specificity of the comparison procedure. Similarly, the absence of points of incompatibility adds weight to the comparison procedure. The weight of evidence conditions the conclusions reached by the forensic dentist. A bite mark represents evidence of the dentition of an individual during a potentially unique episode of contact with the skin. Variation in the episode of contact is illustrated in multiple bite marks, produced by a single dentition in one victim, which vary in appearance.

9.2 DISTORTION

Distortion is the major complicating factor in bite mark analysis. Distortion can be classified into four types - tissue distortion, dynamic distortion, posture distortion and photographic distortion. Tissue distortion and dynamic distortion are complex and unpredictable phenomena which are closely related because of their simultaneous occurrence during the episode of contact between the dentition and the skin. Posture distortion and photographic distortion occur during evidence recording and consequently provide an additional element of distortion superimposed on tissue distortion and dynamic distortion.

During evidence recording, failure to reconstruct the victim's body position at the time of biting produces posture distortion. The degree of posture distortion depends on the variation in body position and the anatomical location. The greater the difference in body position between the time of biting and evidence recording, the greater the degree of posture distortion. Different anatomical locations potentially demonstrate varying degrees of posture distortion. In bite mark cases involving an anatomical site which is potentially liable to posture distortion, the victim's body position during the episode of biting is a significant factor. As the potential liability to posture distortion at a particular anatomical site diminishes, the significance of the victim's body position diminishes correspondingly.

In order to minimise posture distortion during photography, it is necessary to attempt to reconstruct the victim's body position at the time of biting. Clearly this ideal is not always possible and if not, it is suggested that bite marks are photographed in a range of positional possibilities. Reconstruction of the victim's known body position at the time of biting or the reconstruction of a range of positional possibilities is most applicable to the live victim. In cases involving a dead victim, the body position is unknown and the reconstruction of a range of body positions is not so readily achieved. Therefore, the potential occurrence of posture distortion may be a more significant factor in dead victims.

The presence of clothing at the time of biting can mask the details in the resultant bite mark. With reference to the female breast, the brassière is clothing which will alter the morphology of the breasts. It is likely that the extent of the alteration in morphology depends on the subject's age, bust size, cup size, breast ptosis and the particular brassière. Therefore, in bite mark cases when a brassière was worn at the time of the biting, the reconstruction of the victim's body position will also depend on the actual brassière being worn. If the bite mark was made in the skin beyond the edge of the brassière, the photography of the bite mark is uncompromised. If the bite mark was made through the brassière, the photography of the bite mark will record an unknown degree of posture distortion related to the absence of the brassière.

9.3 BITE MARK CASE REVIEW

The review findings in Chapter 2 that the most commonly bitten anatomical location in females was the breast compared favourably with Vale and Noguchi (1983).

Rawson et al (1984a) stated that, if the correlation was high between the bite mark and the dentition, there could be an assurance that no other dentition could have caused the mark as long as the individual tooth marks were within ± 1 mm of centre point and ± 5° angle variation of each individual tooth. Clearly, the validity of Rawson's criteria only apply to a good quality bite mark which represents the incisal edge/cuspal anatomy accurately and completely. As the quality of the bite mark diminishes, the validity of Rawson's criteria correspondingly diminishes. This was reflected in the retrospective study which consisted of bite mark cases which demonstrated a range in the quality of the bite marks; good quality individual tooth elements formed the minority group. Consequently, the validity of Rawson's criteria in bite mark cases remains to be determined.

The retrospective study showed that there was a large element of subjectivity in bite mark analysis. Subjective judgment was found to be an important variable factor in bite mark analysis. Subjective judgment was dependent on the questions posed and the ability and experience of the forensic dentist.

9.4 PRELIMINARY AND MAIN STUDIES

The female breast is a commonly bitten anatomical site which is potentially liable to posture distortion. The preliminary study demonstrated posture distortion in two subjects which was comparable to that in a bite mark case. The main study quantified posture distortion in the female breast, compared posture distortion in multiple axes of four breast sites and studied the influence of arm movement on posture distortion in 20 subjects. In addition, the main study assessed the significance of the age, bust size, cup size, ptosis index and various arm movements to posture distortion. The subjects were selected on the basis that they represented a range of age, bust size and cup size in a sample of the adult female population.

The main study recorded maximum expansion values of 6% to 39% and maximum contraction values of 5% to 29%. The effects of these ranges of posture distortion on an intercanine distance of 34 mm are potential maximum posture distortion values of 13mm expansion and 10mm contraction. Posture distortion of this magnitude is of major clinical significance in bite mark analysis.

The main study showed that the maximum expansion and contraction values were produced almost exclusively by the most extensive arm movements and these were found in the outer, upper and nipple sites. Maximum posture distortion was mainly related to older subjects with a larger cup size and an increased ptosis index. Age and ptosis were found to be positively correlated; an increase in the subject's age was related to an increase in the ptosis index.

The main study demonstrated that age and ptosis were often statistically significant factors, bust size was rarely a statistically significant factor and cup size was the most frequent statistically significant factor. The differences in the frequency of the statistically significant factors suggest that the victim's age, breast ptosis and cup size are the most significant factors in bite mark analysis . The clinical significance of age was that the increase in age was mainly related to an increase in the magnitude of distortion in the four axes; an increase in ptosis was related to an increase in the magnitude of distortion in the four axes and was predominantly related to a decrease in the magnitude of distortion in the vertical axis; an increase in bust size was mainly related to a decrease in the magnitude of distortion in the vertical and diagonal axes; an increase in cup size was related to an increase and a decrease in the magnitude of distortion in the four axes. The clinical significance of age and of bust size were relatively consistent whereas the clinical significance of ptosis and of cup size were contradictory.

The texture of the skin surface of the outer, upper and inner breast sites was comparable; however, the skin surface of the nipple site differed from the other sites.

The influence of the different skin surface of the nipple site was not assessed in the research. The validity of comparing the posture distortion of the outer, upper and inner sites was justified, whereas, comparison with the nipple site was not. The preliminary study demonstrated that posture distortion of the left and right breasts was comparable in the outer, upper and inner sites and was less comparable in the nipple site. The findings were consistent with the nature of the texture of the skin surface of the four breast sites.

The main study was limited to the left breast due to the volume of data. Based on the preliminary study findings, it is anticipated that further research of the right breast would produce comparable results with the main study. The measurements selected for analysis in the main study reflected the major dimensions encountered in bite mark cases.

The horizontal, vertical and diagonal measurements were recorded by the programmed computer as the straight-line measurement between two selected points. However, the six measurements demonstrated distortion which involved varying degrees of minor curvature. The curvature of the measurements was not recorded; this omission was not considered to be of importance. Clearly, the research of posture distortion of straight-line measurements which underwent major curvature would require a different computer programme. Similarly, the research of posture distortion of arch curvature would require an alternative programme.

9.5 PRACTICAL APPLICATION

In bite mark analysis involving the female breast, the anatomical site of the bite mark, the victim's age, bust size, cup size and breast ptosis are relevant factors. The problem for the forensic dentist is the unquantified tissue and dynamic distortion present in the bite mark. Posture and photographic distortion may be minimised during evidence recording; if this is not possible, an attempt is made to quantify posture and photographic distortion. This introduces the concept of the prediction of posture distortion in bite mark analysis. The main study demonstrated posture distortion produced by various arm movements in a specific body plane. The findings of the clinical significance of age and of bust size were relatively consistent whereas the clinical significance of ptosis and of cup size were contradictory. In view of the specific anatomical relationships and the contradictory findings, the prediction of posture distortion in the female breast would require further research. The degree of posture distortion in a bite mark case involving the female breast may or may not be validated by reference to the research findings. Clearly, it would not be possible to predict the posture distortion in a bite mark case involving the female breast using present knowledge.

9.6 FUTURE RESEARCH

Posture distortion was produced by arm movement in a selected plane, namely, vertically by the subject's side. The selected plane has a specific anatomical relationship with each of the four axes in each of the four breast sites. Consequently, the posture distortion values were related to four specific anatomical relationships in each site. The extent and direction of arm movement, within the selected plane, were subject to variation. In this way, the influence of arm movement was assessed. The findings that generally maximum distortion occurred in the horizontal axis in the four breast sites and maximum distortion was lowest in the inner site were dependent on the specific anatomical relationships. Clearly, posture distortion produced by arm movement in alternative body planes would require further research.

The creation and photography of the study marks in the preliminary and main studies were conducted on standing subjects. Therefore, posture distortion related to the breast morphology of standing subjects. The variation in breast morphology between standing and supine subjects is marked, particularly with an increase in age and/or size. Therefore, posture distortion in vertical subjects would differ from horizontal subjects. Further research would be appropriate to quantify posture distortion in supine subjects. Indeed, the technique could be applied to other relevant anatomical sites which are potentially liable to posture distortion. In this way, a scientific database of posture distortion values and significant factors would be created.

The relationship of the subjects' data and the posture distortion percentage values were determined by the statistical analysis of single variables in relation to the data. Consequently, the graphs of the significant correlations reflected the analysis of single variables and therefore the interpretation of the graphs was limited. In order to determine the inter-relationships of all the subjects' variables, multi-variate analysis would require to be undertaken.

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