Optimization of Incisions in Cutaneous Surgery including Mohs' Micrographic Surgery.

The validity of paradigms in skin surgery

Het optimaliseren van de incisievorm bij cutane chirurgie waaronder de Mohs' Micrografische Chirurgie.

Een validatieonderzoek van paradigma van cutane chirurgie

Proefschrift

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“Je le pansay et Dieu le guarist"

(I dressed the wound and God healed it)

Ambroise Paré‘s motto, as inscribed above his chair

in the Collège de St-Cosme (1510-1590).

This work is dedicated to my late mother Tova.

Contents

Chapter 1

General Introduction

Introduction to rational surgery

Tradition has been a restraining barrier in the process of converting surgery from empirical craft into a scientific discipline. For centuries many surgeons were committed to seeing and believing what they were taught rather than believing what they saw (1). Innovators, always in the minority, were people who abandoned theories when their observations conflicted with what they had been taught.

The French barber-surgeon Ambroise Paré is considered the "father of rational surgery". Paré's pioneering work was chiefly in the department of military surgery, when in 1536 he introduced a scientific and humane treatment for battlefield wounds (2). Prior to his work surgeons stopped bleeding wounds by pouring boiling oil on them. Ambroise Paré discovered that treatment of gunshot wounds by boiling oil was worse than leaving them alone or covering them with other materials. His findings were accidental because he ran out of oil, and as a stopgap he tried a cold mixture of egg yolks, oil of roses, and turpentine (3). This coincidence also created two test groups, and as the soldiers healed, the ones who were not burnt with boiling oil recovered far more quickly than those who were. Paré, who was a gifted observer, created a new concept in medicine and surgery: questioning current treatments, testing alternatives, creating two groups, observing, comparing and then concluding what he saw. In 1545 Paré authored a short treatise on the treatment of gunshot wounds based upon his observations. This short practical volume was the first in a lifetime of voluminous medical manuals (4). In addition, Paré invented several surgical instruments and surgical techniques. Among them: truss for hernia, artificial limbs, reimplantation of teeth and ligating arteries instead of cauterizing vessels during amputation. Although suturing and ligating were already used in the Aztec-Mexican medicine (5), their wide use began only after Paré's work. Paré's pioneering work set a frame for future generations in surgery and was a milestone in incorporating scientific studies into medicine.

During the next centuries, general surgery, plastic surgery and dermatosurgery were tremendously developed focusing on establishing surgical techniques (6). Later the focus turned to spreading this knowledge through written textbooks, tutoring, training new generations and establishing professional surgical associations (7, 8)

Until recently, the clinical training of residents was based on an apprenticeship model in which the residents learned medicine and surgical techniques from experienced attending doctors. The apprenticeship model is gradually being transformed from pure experience-based medicine and surgery to an evidence-based medicine. The development of a surgeon's judgment based on the physician's practice and experience is important (9). However, even the most experienced physician may be influenced by recent occurrences in selected patients or anecdotal experiences. Currently, the importance of using a more objective and systematic approach for making decisions and treatments is being established (10). A new model for medical practice emerged a decade ago, which diminishes intuition, unsystematic clinical experience and rational explanations, as sufficient grounds for clinical decisions (11). This new model is called Evidence-Based Medicine (EBM), which integrates individual clinical expertise with the best available external clinical and research evidence from systematic data. It is defined by Sackett as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (12). Evidence Based medicine became the standard of treatment from the patient perspective on the one hand, and from the health care system and the physician perspective on the other hand. Providing evidence based care improves outcomes for patients (12). Choosing an optimal intervention procedure is also becoming a must in the current financial restrictions that tend to reduce health care expenditure (13). For these two reasons, as well as the superior systematic approach, physicians increasingly tend to treat patients based on satisfactory evidence (14,15).

In practicing EBM the need for information is converted into a question answered by the current best evidence resources such as textbooks and electronic databases. This information is finally integrated with the clinical expertise (16). The best evidence resources are prospectively designed, double-blind, placebo-controlled randomized clinical trials. They represent the "golden standard", yet not the only source, of evidence regarding therapeutic decisions. Valuable evidence may stem from prospective cohort studies and analytical surveys. Evidence is strengthened immensely after it has been confirmed in multiple investigations. The sources may be compared with one another and presented in a meta analysis or systematic overview (17). The skill of rapid access to the best available evidence is not sufficient for optimum treatment. The ability of a physician to apply sound evidence in a particular situation in a patient is becoming the state-of-the-art in medicine.

In this study the excisional biopsy incisions are explored. The importance of such study lies in preserving healthy tissue and shortening of scars. If sparingly used, the saved skin may serve as a future resource for reconstruction, a flap, for instance. In order to study these incisions a brief overview of excisional biopsy techniques, Mohs' micrographic surgery (MMS), surgical ellipse closures and the phenomenon of dog-ear creation are presented. An insight into the principles of these physiological dynamics is essential to solve the skin-related problems which arise during and after performing these procedures.

Excisional biopsy technique

In cutaneous biopsy a piece of skin is removed from a patient in order to investigate whether the probed area is benign or malignant and to confirm the diagnosis in suspected cases. The removed specimen is pathologically examined and processed. An excisional biopsy is the removal of the entire lesion with some additional normal tissue as margins. For the complete removal of the lesion these margins are small if the lesion is deemed benign (18), or large if the lesion is clinically suspected to be malignant (19-22). If there is a residual tumor, simple re-excision or MMS are undertaken. The latter is the best local intervention to remove the residual tumor (23-29).

Many skin lesions are circular, yet the final excision pattern is often different. Surgeons do not simply cut a circle around the lesion to remove it, even though a circular cut removes less skin and leaves a shorter scar than any other skin excision. The reason is that a circular excision does not stitch very well when directly closed. It leaves an elevated skin bunched up at the ends. This excess skin at the wound apices is called "dog-ear", because its shape resembles a pointed ear on a dog's head (Figure 1).

Cuts of an unequal width and length on the skin are easier to close and produce less tissue protrusion and dog-ear formation compared with a circular pattern (30). The cut is chosen after determining the necessary extent of excision that includes the lesion and the margins. The specimen is designed such that it provides an adequate amount of tissue for pathological examination. After marking the lesion to be removed and its margins, a cutting pattern surrounding the lesion is drawn. The short axis of the cutting pattern, or width, is the diameter of the lesion whereas the long axis exceeds the width by a certain factor (Figure 2).

Several cutting patterns have been described in the literature. Among them are the ellipse, rhomboid, s-shape, mosque and circular incision (Table 1). The objective in cutaneous plastic surgery is to remove the lesion and yet to obtain an esthetical and functional scar. Skin scars need be designed for minimal scar length, minimal healthy tissue waste, a well oriented scar confined to a single cosmetic unit and without any damage to tissue function (31). A hidden incision yields the best scar, as seen in closed rhinoplasty or in a scar hidden by hair. If the scar is visible, it should be restricted to the subunit and to the favorable skin tension lines, for instance the cosmetic result is optimum when the final scar is in a wrinkle. All these factors should be taken into consideration when a certain skin cut is planed for an excision.

Mohs' Micrographic Surgery

The incidence of skin cancer rates have continued to rise during the last few decades (32). Skin cancers make up a half of all cancers diagnosed (33-4) with a total estimated number of 54,000 new cases of malignant melanoma (35) and over 1,200,000 new cases annually of non melanoma skin cancer (36,37) in the USA. These numbers are most likely to be underestimates of the true tumor incidence, because not all of the skin cancers are registered and because many patients with such tumors are treated in private medical practices. Complete removal of the tumor is mandatory, whereas incomplete excision or neglected lesion may result in an invasion of cancer cells into deeper layers, destroying local vital structures, and eventually causing metastasis and possibly death. Excisional surgery is effective for skin cancer and is the mainstay of therapy (38,39).

Mohs' micrographic surgery was developed by Dr. Frederick Mohs at University of Wisconsin in the 1930s (40). The technique and its modifications focus on complete surgical excision of the tumor with immediate microscopic examination of horizontal frozen sections (41). The operation begins by cutting the cancerous lesion with some margins. The first layer is removed by a saucer shaped incision. This saucer incision was recommended by Dr. Mohs' to obtain adequate number of frozen sections. The specimen's margins are color-coded in the laboratory, and any residual tumor at the margin is mapped. Additional excisions are performed according to this Mohs' map (Figure 3). The operation is completed when all the residual tumor has been removed (42).

In the past twenty years, MMS has been recognized as a superior treatment for some non melanoma skin cancers (43 – 46) and may also present advantages in treatment of melanoma tumors (47,48). It should be mentioned that large, prospective, long term follow up studies for deferent treatment modalities are lacking in the literature. There are, however, systematic review articles concerning treatment options in skin cancer. Three of such articles describe that MMS has the lowest recurrent rate for both primary and recurrent basal cell carcinoma (43,44,45). The five years recurrent rates for non Mohs modalities are reported as 8.7%, on the average, while the recurrent rates for the same tumor treated by Mohs technique is 1%. Similar results were found in previously treated basal cell carcinoma. The five years recurrence rate was 17.4% for surgical excision, 9.8% for radiotherapy, and 40% for curettage and electrodessication. In comparison, Mohs' microscopic surgery recurrence rate for the same cancer was only 5.6%. Consequently, the MMS technique offers an extremely high cure rate (44) while minimizing skin waste, which often allows for the preservation of functions, and an optimal esthetic outcome (49). Considering the effectiveness of MMS in minimizing local recurrence and bearing in mind that it is performed under local anesthesia in an office setting, the procedure is cost-effective. In the past decades MMS has been modified. The fixed tissue technique (chemosurgery) has been replaced with a fresh tissue technique that makes the procedure less painful, shorter and permits immediate reconstruction (23).

The surgical ellipse

The surgical ellipse, also known as a fusiform ellipse (50, 51), is the classical approach for removing cutaneous lesions. A geometrical ellipse on the one hand possesses a rounded apex, which is difficult to both incise and close. A surgical ellipse on the other hand, is the overlapped zone of two ellipses or two circles (Figure 4), thus producing two vertices. An excision having this shape is preferred because of the subsequent ease of planning, cutting and closing. The fusiform ellipse is incised perpendicular to the skin, yielding a straight-line specimen and wound. The specimen's borders are clear when observed microscopically and the straight borders of the wound are easy to close, resulting in a thin, flat scar.

As a general rule, the traditional recommendation in the literature is to form ellipse dimensions that have a length-to-width ratio between 3:1 to 4:1 (52, 53), and an apical (vertex) angle of 30° or less. This ratio results in longer scars compared with the original round lesion diameter, but it permits primary closure of the wound without creating dog-ears (54-60).

The open wound created after incising the lesion can be closed by either a primary closure or by skin graft and flap. Of these, the primary closure is superior yielding optimum esthetic results. Therefore, the focus of the present study was on direct and primary closures.

Tissue dynamics in basic local flaps

Skin is a viscoelastic material whose complex mechanical properties include the elastic properties of solid materials and the viscous properties of fluids (61). The elastic characteristics of the skin relate to the immediate changes that occur when force is applied to the skin. They govern the ability of the skin to deform, i.e. to stretch, contract and compress. These characteristics are defined by two physical constants namely the Young's modulus, which relates the proportionality of the longitudinal deformation to the applied force (Hooke's law), and Poisson's ratio, which relates the dimensional deformations to one another (62). The viscous characteristics of the skin relate to the delayed changes occurring after time: the decrease in stress over time when a constant strain is applied (the stress relaxation effect) and the increase in length over time when a constant strain is applied (the creeping effect) (63). Surgeons are familiar with these effects and count on the stress relaxation effect to release the tension in scar with time. They use the creeping effect to absorb some irregular scar features and dog-ears and to cause tissue elongation after inflating expanders.

Advancing movement and rotating movement are two main movements that can be applied to the skin. The two are vastly used in reconstructive surgery (64, 65). The transpositions of skin tissues may be manipulated by either of these basic movements or any combination thereof such as Millard's rotation-advancement cheiloplasty (66). The two basic movements are described below.

a. Advancement movement

In an advancement movement the tissue is transferred from the donor to the recipient site by a linear shift in the same plane. The dynamic change of the advancement movement stretches the tissue and exerts tension at the center of the movement or flap (Figure 5). Excess tissue is formed at the flap base or movement. To overcome the discrepancy in tissue elongation during the advancement across the flap, two small triangles at the base, referred to as Bürow's triangles, should be excised (67) (Figure 6). The advancement movement is usually used to close a square defect.

b. Rotational movement

In the rotational movement the tissue is transferred from the donor to the recipient site by an angular movement (Figure 7). This movement is usually used to open or close a circular or triangular defect. All rotation flaps produce tissue protrusion on the outer perimeter (Figure 8). This can be corrected by removing the excess tissue.

The result of a rotational movement is an angular manipulation that produces a conical skin deformation around the pivot (68). Formed are two kinds of cones: vertical and horizontal. A vertical cone is produced on rotating a flap to close an incised sector (Figure 9). Its axis is at a right angle to the skin surface. In this case there is a shortage of tissue in the lesion (horizontal) plane and an excess of tissue above or beneath this plane (Figure 10). When there is enough supporting tissue beneath, the standing cone produced is upright and everted, when there is no support beneath, the cone is pushed under the surface creating an inverted, or a sunken dog-ear. In dog-ear formation, the smaller the angle to be closed, the smaller is the angle of rotation, and the smaller is the cone protrusion (Figure 11). For an apical angle smaller than 30°, the protruding tissue is considered negligible and a dog-ear is hardly observed (68). Figure 10 is as Figure 11, however viewed from a different angle, emphasizing the point that the base of the flap is narrower for a larger apical angle creating a larger protrusion.

A horizontal cone is produced on rotating a flap to open an angle and insert a tissue sector (Figure 12). It is also formed when the wound to be closed possesses unequal arc lengths (69, 70). The central axis of a horizontal (laying) cone is at an acute angle to the skin surface. In comparison with a vertical cone, there is excess of tissue both in the horizontal and the vertical planes, either above or beneath the lesion plane. The horizontal cone occasionally appears as multiple wrinkles or rippling of the skin (Figure 13) radiating from the opened angle. The laying cone is often referred to as pseudo dog-ear.

Tissue dynamics in closure of surgical ellipse

The surgical ellipse is an excision comprising two arcs that together constitute a perimeter. On closure of an elliptical defect each of the arcs is pulled towards an imaginary meridian such that the scar follows the meridian. In fact one performs two closures, between each of the arcs designated as A, and the meridian designated as M (Figure 14). Dog-ears are formed at the vertices because these two closure lines possess uneven lengths (71) (Figure 15).

The moving zones along the ellipse can be divided into two areas: the center and the apex. During closure different movements such as advancement, rotation, and a hybrid rotation-advancement are observed in each zone. Pure advancement movement is observed at the center of the ellipse whereas pure rotation movement is observed at the two ellipse vertices (Figure 16). Upon closing, the central zone of the ellipse moves in an advancing manner and traverses the greatest distance, thus creating tension in the central zone of the scar (Hooke's law). The apical zones move rotationally thus forming tissue puckering or dog-ears (Figure 16). All the other ellipse points that are not central or apical move in a hybrid rotation-advancement.

The tension created in the scar center is proportional to the traversed distance, or the ellipse width. The dog-ear protrusion at the vertices is a function of the apical angle. In fact the two latter effects depend on one another such that the greater the discrepancy between the ellipse length and the arcs, the greater is the vertex angle and skin protrusion. A circular excision is the extreme case of the discrepancy between the ellipse length and the arcs with the largest vertex angle (180°) (Figure 17). Therefore, a circular excision by definition creates the highest tension in the center and consequently, the largest dog-ear protrusion at the vertices (Figure 18). Accordingly, any other cutting pattern possessing a long and a short axis is superior to the circular excision. Classical elliptical techniques recommend an excision with an ellipse length that is 3 to 4 times the ellipse width (72). This general rule is used to obtain an acute angle of 30º or less at the vertex. Such an ellipse can always be closed primarily without excessive tension and with a lower tendency to form a dog-ear (73).

The ability of the skin to overcome the shortage of tissue at the center and the excess of tissue at the apex depends on its aforementioned elastic and viscoelastic properties (61). Explicitly, the skin may compensate for tensions and wrinkles and even by absorb protrusions without breaking or tearing.

Correction of dog-ear

The term dog-ear is deeply embedded in surgical parlance (74) and has become an intimidating term to surgeons. Dog-ear is the result of rotated skin created by: 1) closure of any cutting pattern with equal arcs possessing an apical angle exceeding 30°, 2) closure of any cutting pattern with unequal arcs, 3) wide angle of rotation at the vertices, 4) closure of a wound located in inelastic skin, or when tissues are bonded to the dermis or subdermis, and 5) closure of a wound located in a convex plane.

Dog-ear or puckering can be repaired by the following approaches:

1. Increasing the length of the ellipse whereby the length-to-width ratio is increased, creating a smaller angle at the vertex and a smaller rotation movement that can be closed without forming a protrusion (55). There are two techniques to achieve this: a) preventing the formation of dog-ear by incising a longer ellipse than the designed ellipse in advance, and b) repairing dog-ear by trimming off the excess tissue after closing the original ellipse (Figure 19). The trimming may be accomplished by either elongating the scar along the main axis (straight one-line dog-ear repair), or by a continued incision at an angle to the ellipse length. This trimming may be a curved one-line dog-ear repair, angled one-line dog-ear repair (hockey stick line, L-shaped line) (Figure 20) or a two-line dog-ear repair (T shape line). A dog-ear repair by trimming is better than directly enlarging the a priori ellipse excision because it spares more tissue (56).
2. Correcting an uneven length of a wound closure. Equalizing the two sides of the excess tissue (80) (Figure 21) may be accomplished by three possible techniques: a) shortening the long arc with a small triangle known as: Bürow's triangle, when at the vertex, and Szymanowski's triangle, when at the center (51, 76, 77). This correction

is a two-line dog-ear repair or a V-shaped line, b) lengthening the shorter arc by adding a right-angled incision at the vertex (78), c) redistributing the excess length by the "rule of halves", a surgical method for dividing uneven lengths (Figure22). In this technique, the initial suture is placed at the center of both arcs. The remaining defects are continually halved by placing suture (79) (Figure 23).

3. A wide angle of rotation may be avoided by dividing the vertex angle and drawing an M-plasty. The shortening of the scar and a less protruding dog-ear are thus achieved (70, 80). This correction is a two-line dog-ear repair.
4. Some of the skin inelasticity or stiffness may be overcome by a wide undermining. A pseudo dog-ear is formed when the dermis and subcutaneous tissues are released unevenly or improperly. Undermining and removing the excess subcutaneous tissue will straighten the pseudo dog-ear (81).
5. Closure of ellipses located on a convex surface may enhance the appearance of the dog-ear. The vertex tissue is pushed farther out relative to the plane, causing the dog-ear to become more visible. Drawing S-plasty instead of the ellipse prevents this phenomenon (82).
6. Doing nothing is also an option. Some spontaneous flattening of dog-ears occurs in time. The reason for this partial absorption is a longitudinal and vertical contraction of the linear scar (51). Therefore, not doing anything to the dog-ear and waiting for a future result is an acceptable option that does not cause any extra scar and requires no excision of healthy tissue. Perhaps in many cases this should be the prime option, following the rule "Primum non nocere".

Circular defect closure

Most of open wounds after excising lesions are circular or oval (83). This section describes the methods to treat circular defects. The open wound may be closed or reconstructed depending on a number factors, including the size and location of the defect, the surrounding tissue, the age of the patient, the patient's preference and the surgeon experience (84). Small size defects in the head and neck area should be considered for direct closure and medium size defects should be considered for closure by local flap. Large defects may be closed by local flaps or skin grafts. Next, location is crucial in areas where small tension or scar may create secondary deformity. Small size defects in the scalp or neck are easy to close whereas the same size defect located on the eyelid may present a problem for reconstruction and may end with an ectropion. The surrounding tissue must be examined to determine if a wound may be closed primarily, with a local flap or graft.

In general there are three options to close a defect: primary, secondary or tertiary closure (85). Many skin defects especially surgical wound may be closed by first intention or primary closure where the wound edges are directly approximated or with some minor variation or modifications such as M-plasty or a purstring. Purstring suture is aimed at directly closing a circular defect or at reducing the size of the wound (86).

Second intention or secondary closure allows the wound to contract and epithelize without formal repair. Wound contraction is an active essential part of wound repair in which the organism closes a gap in the soft tissues (52, 87,88). The second intention approach yields nice small contracted scars when the wound is small or an excessive contraction with esthetic deformity, such as ectropion or contracture deformity (89), when the wound is large. This method achieves good esthetic results especially for wounds placed on a concave surface, for instance: nose, eye and ear. (90)

The next option is third intention or tertiary closure, a surgical closure by bringing tissue from elsewhere in the form of flap or graft.

Skin grafts can be classified as either split thickness consisting of the epidermis and part of the dermis or full thickness grafts including the entire thickness of the skin (91-93). The best donor sites for head and neck grafting are considered to be the preauricular, post auricular and supraclavicular areas. The advantages of using a skin graft are its being a simple technical procedure and the ability to recruit large amounts of skin for closing large defects. Yet, skin grafts in the head and neck region do not always fully survive, appearing pale or more pigmented than the surrounding skin (94) and leave additional scars at the donor site. Skin grafts are used to close circular defects in locations that are difficult to close primarily or to be reconstructed by a flap. An example includes small size defects in the medial canthus or lower eyelid (Figures 24,25) and large size defects located in the temporal area. When a wound defect has a tumor at high risk for recurrence, grafting or second intention healing may be the treatment of choice (95).

Flaps present another option for tertiary closure. Using local flaps bring skin with similar color and texture to the defect, and there is frequently little or no scar contracture with the use of flaps (96). The major problems with the use of local flaps are that they require planning and experience. In addition, all flaps have the disadvantage of creating excess scars in the donor site. Most local flaps are random in their vascular supply therefore they are not classified by vascular pattern but rather according to the flap movements. There are only two basic movements available to the skin: advancement and rotation (83) and a combination thereof.

Advancement flap slide, stretch and push tissue into the defect. A round defect can be closed by a single advancement flap or by a double advancement flap that results in an H shaped scar. A single advancement flap can be used when a round defect is on the lateral eyebrow, then the flap movement will add length to the lateral brow (83). A single advancement flap (Pang flap) can be also used for reconstructing a round defect in the nasal tip (97). This flap conforms perfectly to the three dimensional shape of the nasal tip while most of the scars are limited to the subunits of the nose being well hidden in the sidewalls (98). A double advancement flap can be used in the forehead or neck where most of the flap scars can be hidden in wrinkles. A bipedicle flap is an advancement flap suitable for closing defects on the forehead, nose, ear, eyelid and chin. Its greatest advantages are that it is a well vascularized flap and its scars can be easily camouflaged (99).

Rotation flap is a semicircular flap that may be used as a single flap or as a double flap (referred to as an O-to-Z flap). These flaps are useful in locations where the arc of rotation may be less noticeable as in the lateral side of the face: preauricular, temporal, and mandibular areas or in the nasolabial area (Figures 26, 27). Among the limitation of rotation flaps one fined some tissue resistance to rotation and the noticeable large dog ear that is created at the rotation pivot. The cheek and the scalp tend to rotate well while the tip of the nose, the ala nasi region and the auricle, rotate poorly. In addition, in order to stretch the flap and achieve lengthening, any back-cut at the base of the flap compromises the blood supply to the flap.

Transposition flap rotates about a pivot into an adjacent defect. The transposition flap has a wide range of uses. The bilobe flap is used on a convex surface as the nose and the Limberg or rhomboid flap and the Dufourmental flap are examples of flaps (100) used to close a diamond shape defects. The nasolabial flap is a transposition flap that interpolates the path between two separated tissues .The related pedicle passed over intervening tissue. The advantages of this flap are a superior donor site and the disadvantages are additional incisions at the donor site and the need for a second intervention, especially to obliterate the nose-cheek junction or to match the flap thickness.

In this section the options to close circular defects were overviewed and were referred to the head and neck region. The same principles can be applied elsewhere in the body.

Objectives of the present study

There were several different objectives of the studies described in this thesis. The two common excisional biopsy techniques namely the surgical ellipse used in general and cutaneous surgery and the saucer excision used in MMS were analyzed. The medical validity of these two axiomatic cuts was questioned and examined. In the initial study, five different excision patterns namely the fusiform ellipse (82, 101-1034), the fusiform circle (104), the rhomboid shape (105,106), the mosque shape and the S-shape (107-109) were theoretically analyzed and examined in details. These were also compared with a circular excision (110).

In the second study, the present paradigm of surgical ellipse dimensions was questioned and a meticulous examination of the accurate proportions of the most common skin pattern was undertaken. The length-to-width ratio and the vertex angle were examined by reviewing the date on ellipses in plastic, general and dermatosurgery (30, 31, 85,110-148).

The issue of what the surgeons use for surgical ellipse dimensions (149) and the waste of healthy skin in these operations was investigated in the next two studies. It was also examined whether there was a relationship between the waste of healthy skin and a specific site or size of the lesion and whether the surgical ellipse was a necessary cutting pattern (150).

The elastic properties of frozen and cancerous skin (151) were examined by determining the elastic constants of Poisson’s ratio and Young’s Modulus (152,153). In the subsequent study the elastic constants that were calculated were used to challenge the saucer incision, a paradigm used in MMS to answer a persisting question on the minimum beveling angle effective for strata projection in a MMS cut (154).

The paradigm of saucer cut and an alternative to the circular incision were further investigated in the next study.

In the final study, the paradigm that a direct closure of circular defects is not feasible without additional surgical manipulation was re-examined (55,155,156) with the aim to find a new technique which would permit a direct closure of circular defects without the need for additional excision.

In summary, defining the most common cutting patterns, investigating them, finding their advantages and disadvantages, understanding the physiology of dog-ear creation, were milestones in exploring paradigms in cutaneous surgery and developing two new surgical techniques: one for general cutaneous surgery and another for Mohs' micrographic surgery.

References

1. Wangensteen OH, Wangensteen SD. Overview. In: Wangensteen OH, Wangensteen SD, eds.The rise of surgery. University of Minnesota press, Minneapolis 1978;3-15.
2. Catholic encyclopedia: Ambroise Paré. http://www.newadvent.org/cathen/11478a.htm
3. Malgaigne, J. F. Surgery and Ambroise Paré. Norman, OK: University of Oklahoma Press, 1965.
4. Rutkow IM. The renaissance. In: Rutkow IM, ed. Surgery and illustrative history. Mosby 1993; 119-185.
5. An Overview of Medical History. http://www.glaciermedicaled.com/history/hxmed01b.html
6. Converse JM. Introduction to plastic surgery. In: Converse JM, ed. Reconstructive plastic surgery. WB Saunders company, Philadelphia. 1964;3-20.
7. Brieger GH. The development of surgery. In: Sabiston DC, ed. Textbook of surgery. The biological basis of modern surgical practice. WB Saunders company 1997;1-15.
8. Rogers BO. History of aesthetic plastic surgery of the face. In: Lewis JR, ed. The art of aesthetic plastic surgery. Little Brown and Company 1989;9-19.
9. Jurkiewicz MJ. Plastic surgery: a conceptual definition. In: Jurkiewicz MJ, Krizek TJ, Mathes SJ and Ariyan S, eds. Plastic surgery principles and practice. CV Mosby company, St Louis.1990; 3-6.
10. Braunwald E, Fauci AS, Kasper DL, Hauser SL, Longo DL, Jameson JL Introduction to clinical medicine. In: Braunwald E, Fauci AS, Kasper DL, Hauser SL, Longo DL, Jameson JL, eds. Harrison's principles of internal medicine, 15 th edition. McGraw-Hill. New York 2001;1-5.
11. Guyatt G, Evidence based medicine working group. Evidence-based Medicine .A new approach to teaching the practice of medicine. JAMA 1992;7:2420-5.
12. Sackett DL, Straus SE, Richardson WS, Rosenberg W, Haynes RB.Evidence-based Medicine: how to practice and teach EBM.1st Ed. New York: Churchill Livingstone, 1997.
13. Howes N, Chagla L, Thorpe M, McCulloch P. Surgical practice is evidence based. Br J Surg 1997;84:1220-3.

14. Ellise J, Mulligan I, Rowe J, Sackett DL. Inpatient general medicine is evidence based. Lancet 1995;346:407-10.
15. Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence-based Medicine: what it is and what it isn't. Br Med J 1996;312:71-2.
16. Berg D, Asgari M, Evidence based medicine for dermatologic surgeons: Concepts in critical appraisal of information. Dermatol Surg 2001;27:511-4.
17. Offer GJ, Perks GB. In search of evidence based plastic surgery: the problem faced by the specialty. Br J Plast Surg 200;53:427-33.
18. Hudson-Peacock MJ, Matthews JN, Lawrence CM. Relation between size of skin excision, wound, and specimen. J Am Acad Dermatol. 1995 ;32(6):1010-5.
19. Thomas DJ, King AR, Peat BG. Excision margins for nonmelanotic skin cancer. Plast Reconstr Surg. 2003 Jul; 112(1): 57-63
20. Breuninger H, Schippert W, Black B, Rassner G. The margin of safety and depth of excision in surgical treatment of basalioma. Use of 3-dimensional histologic study of 2,016 tumors. Hautarzt. 1989;40 (11):693-700
21. Brodland DG, Zitelli JA. Surgical margins for excision of primary cutaneous squamous cell carcinoma. J Am Acad Dermatol. 1992; 27:241-8.
22. Thomas JM, Newton-Bishop J, A'Hern R, Coombes G, Timmons M, Evans J, Cook M, Theaker J, Fallowfield M, O'Neill T, Ruka W, Bliss JM, United Kingdom Melanoma Study Group, British Association of Plastic Surgeons, Scottish Cancer Therapy Network. Excision margins in high-risk malignant melanoma. N Engl J Med. 2004;350:757-66
23. Lang PG Jr. The role of Mohs' micrographic surgery in the management of skin cancer and a perspective on the management of the surgical defect. Clin Plast Surg. 2004;31:5-31.
24. Shriner DL, McCoy DK, Goldberg DJ, Wagner RF Jr. Mohs micrographic surgery. J Am Acad Dermatol. 1998;39:79-97.
25. Malhotra R, Huilgol SC, Huynh NT, Selva D.The Australian Mohs database, part II: periocular basal cell carcinoma outcome at 5-year follow-up. Ophthalmology. 2004;111:631-6.
26. Gloster HM Jr, Harris KR, Roenigk RK. A comparison between Mohs micrographic

surgery and wide surgical excision for the treatment of dermatofibrosarcoma protuberans. J Am Acad Dermatol. 1996;35:82-7.
27. Zitelli JA, Brown CD, Hanusa BH. Surgical margins for excision of primary cutaneous melanoma. J Am Acad Dermatol. 1997; 37: 422-9.
28. Tromovitch TA, Beirne G, Beirne C. Mohs' technique treatment of recurrence cutaneous carcinoma. Cancer 1966;19:867.
29. Rowe DE, Carroll RJ, Day CL. Mohs surgery is the treatment of choice for recurrent basal cell carcinoma. J dermatol Surg Oncol 1989;15:424-431.
30. Borges AF. Dog ear repair. Plast Reconst Surgery 1982;69:707-13.
31. Leshin B. Proper planning and execution of surgical excisions. In: Wheeland RG,ed. Cutaneous surgery. W.B.Saunders company;1994:171-177.
32. Gloster HM, Brodland DG. The epidemiology of skin cancer. Dermatol Surg 1996;22:217-26.
33. Marks R. An overview of skin cancer. Incidence and causation. Cancer 1995;75:607-12.
34. Miller DL, Weinstock MA. Nonmelanoma skin cancer in the United States: incidence. J Am Acad Dermatol. 1994;30:774-8.
35. http://www.infoplease.com/ipa/A0883543.html
36. Geller AC, Annas GD. Epidemiology of melanoma and nonmelanoma skin cancer. Semin Oncol Nurs. 2003;19:2-11.
37. Higashi M.K.; Veenstra D.L.; Langley P.C. Health Economic Evaluation of Non-Melanoma Skin Cancer and Actinic Keratosis. PharmacoEconomics 2004;22:2:83-94.
38. Preston DS, Stern RS. Nonmelanoma cancers of the skin. N Eng J Med 1992;325:23:1649-62.
39. Krown SE, Chapman PB. Defining adequate surgery for primary melanoma. N Eng J Med 2004;350:8:823-5.
40. Mohs FE.Chemosurgical method for microscopically controlled excision of cancer.Am J Proctol. 1957;8:273-82.
41. Robins P, Albom MJ. Mohs' surgery-fresh tissue technique.J Dermatol Surg. 1975 ;1:37-41.
42. Mohs FE. Chemosurgery. Clin Plast Surg. 1980;7:349-60.

43. Thissen MRTM, Neumann MHA, Schouten LJ. A systemic review of treatment modalities for primary basal cell carcinoma. Arch Dermaol 1999;135:1177-83.
44. Rowe D,Carroll R, Day C. Long term recurrent rates in previously untreated (primary) basal cell carcinoma: Implications for patient follow-up. J Dermatol Surg Oncol 1989;15:315-28.
45. Rowe D,Carroll R, Day CL. Mohs surgery is the treatment of choice for recurrent (previously treated) basal cell carcinoma. J Dermatol Surg Oncol 1989;15:424-31.
46. O'Connor WJ, Roenigk RK, Brodland DG. Merkel cell carcinoma. Comparison of Mohs micrographic surgery and wide excision in eighty-six patients. Dermatol Surg. 1997;23:929-33
47. Wacker J, Khan-Durani B, Hartschuh W. Modified Mohs micrographic surgery in the therapy of dermatofibrosarcoma protuberans: analysis of 22 patients.Ann Surg Oncol. 2004;11:438-44.
48. Bienert TN, Trotter MJ, Arlette JP. Treatment of cutaneous melanoma of the face by Mohs micrographic surgery.J Cutan Med Surg. 2003;7:25-30.
49. Mohs FE. Mohs micrographic surgery. A historical perspective. Dermatol Clin. 1989;7:609-11.
50. Dunlavey E and Leshin B. The simple excision. Dermatol Clinics. 1998;16(1):49-64.
51. Bennett RG .Complex closures. In: Bennett RG, ed. Fundamentals of cutaneous surgery. C.V. Mosby Company;1988:473-491
52. Wound closure. In: Rohrich RJ and Robinson JB, eds. Wound healing. Selected readings in plastic surgery. University of Texax southwestern medical center and Bayelor University medical center;1999:9(3):18-20.
53. McCarthy JG. Introduction to plastic surgery. in: McCarthy JG, ed. Plastic surgery. W.B. Saunders Company 1990;1-54.
54. Wound care, and flaps, pedicle and tubes. In: McGregor IA, ed. Fundamental techniques of plastic surgery and their surgical applications. E & S Livingstone Ltd. Edinburgh and London 1960;3-39, 39-141.
55. Hudson-Peacock MJ and Lawrence CM. Comparison of wound closure by means of dog ear repair and elliptical excision. J Am Acad Dermatol 1995;32:627-30.
56. Hudson-Peacock MJ, Lawrence CM. Excision with dog ear repair is superior to

elliptical excision. Br J Dermatol 1993;129(42):48.

57. Dzubow LM. The dynamics of dog ear formation and correction, J Dermatol Surg Oncol 1985;11:722-8.
58. Robertson DB. Dog ear repair. In: Wheeland RG, ed. Cutaneous surgery. W.B.Saunders Company, 1994;295-303.
59. Dog ear repair. In: Rompel JPR,ed. Operative dermatologie. Lehrbuch und atlas. Springer 1996;54-55.
60. Complex excision. In: Fewkes JL, Cheney ML and Pollack SV, eds. Illustrated atlas of cutaneous surgery. J.B. Lippincott Company. Philadelphia 1992;16.1-16.8.
61. Gilbson T, Kenedi RM. Biomechanical properties of skin. Surg North Am 1967;47:279-294.
62. Lee C, Vincent JF, and Hillerton JE. Poisson's ratio in skin. Biomed Matwe Eng. 199;1(1):19-23.
63. Wexler DB, Gilbertson LG, Goel VK, Bardach J. Biomechanics of the rotation-advancement skin flap: experimental and theoretical studies. In: Bardach J, ed. Local flaps and free skin grafts. Mosby year book, 1992. 53-68.
64. Advancements flaps. In: Davidson TM, Webster RC, and Gordon BR,eds. The principles and dynamics of local flaps. American Academy of Otolaryngology - Head and neck surgery foundation, Inc 1998;26-8.
65. Le surjets. In:Letessier S, Bachellier-Beuzelin Y, and Grognard C,eds. Manuel partique de chirurgie dermatologique. Masson, Paris 1986;35-38.
66. Millard DR. Refinements in rotation-advancement cleft lip technique. Plast Reconstr Surg 1964;33:26-9.
67. Jackson IT. General consideration. In: Jackson IT, ed. Local flaps in head and neck reconstruction. The CV Mosby Company, 1985. 1-34.
68. Limberg AA. Design of local flaps. In: Gibson T,ED. Modern trends in plastic surgery. Butterworth & co. London. 1966;38-61.
69. Vaughan TK, Samlaska CP, Mulvaney MJ. Hello tricone; good-bye "dog-ear". Arch Dermatol. 1990 Oct;126(10):1366.
70. Weisberg NK, Nehal KS, Zide BM. Dog-ears: a review. Dermatol Surg 200;26:363-70.

71. Mizunuma M, Yanai A, Tsutsumi S, Yoshida H, Seno H, Inoue M, and Nisbida M. Can dog ear formation be decreased when an s shape resection is used instead of spindle skin resection? A three dimensional analysis of skin surgery techniques using finite element method. Plast Reconstr Surg. 2000;106(4):845-8.a
72. Weinzweig J, Weinzweig N. Techniques and geometry of wound repair. In: Weinzweig J, ed. Plastic surgery secrets. Henley and Belfus, Inc, Philadelphia.1999. 6-13.
73. Robertson DB. Dog ear repair. In: Wheeland RG, ed. Cutaneous surgery. W.B.Saunders Company, 1994;295-303.
74. Complex closure. In: Bennett RG,ed. Fundamentals of cutaneous surgery. The C.V. Mosby Company 1988;473-91.
75. Dog-ear repair and closure of sides of unequal length. In: Stegman SJ, Tromovitch TA, and Glogau RG,eds. Basics of dermatologic surgery. Year Book Medical Publishers, Inc. Chicago, London 1982;69-72.
76. Goldwyn AM. Carl August Bürow. Plast Reconstr Surg 1984;73(4):687-690.
77. Bürow A. Symanowski und Uhde's Kritik der methode der seitlichen Dreiecke. Berl Klim Wochensch 1870;8:350.
78. Grabb WC. Basic techniques in plastic surgery. In: Grabb WC, and Smith JW, eds. Plastic surgery. A concise guide to clinical practice. Little, Brown and Company, Boston 1973;3-74.
79. Maloney M. Basic skin surgery techniques. In: Harper J, Oranje A, and Prose N, eds. Textbook of pediatric dermatology. Blackwell Science 2000;1767-80.
80. Weisberg NK, Nehal KS, Zide BM.Dog-ears: a review. Dermatol Surg. 2000 Apr;26(4):363-70.
81. Leffell DJ, Brown MD: Basic excisional surgery. In: Manual of Skin Surgery: A Practical Guide to Dermatologic Procedures. 1997:149-80.
82. Rosemberg L. A versatile procedure for the closure of small skin defects. Aesthetic Plast Surg 1985;9:23-6.
83. Whitaker DC. Random pattern flaps. In: Cutaneous surgery. Wheeland RG,ed. WB Saunders Company 1994;329-52.
84. Bardach J. Analysis of defects in the head and neck area and planning of

reconstruction using local flaps and free skin grafts. In: Local flaps and free skin grafts. Bardach J,ed. Mosby Year Book 1992;69-86.
85. Stasko T. Advanced suturing techniques and layer closure. In: Wheeland RG,ed. Cutaneous surgery. W.B.Saunders Company 1994;304-17.
86. Krizek TJ. The problematic wound. In: Plastic surgery secrets. Weinzweig J,ed. Hanley and Belfus, Inc. Philadelphia 1999;29-33.
87. Rudolph R. inhibition of myofibroblasts by skin grafts. Plast Reconstr Surg 1979;63:473- 8.
88. Majno G, Gaddiani G, Hirshel BJ et all. Contraction of granulation tissue in vitro: similarity to smooth muscle. Science 1971;173:548-50.
89. Harris DR. healing of the surgical wound. J Am Acad Dermatol 1979;1:197-207.
90. Zitelli JA. Wound healing by second intention. J Am Acad Dermatol 1983;9:407-15.
91. Vitnes LM. Grafting of skin. Surg Clin North Am 1977;57:939- 45.
92. Flowers r. Unexpected postoperative problems in skin grafting. Surg Clin North Am 1970;50:439- 43.
93. Lopez-Mas J, Ortiz-Monasterio, Degonzales MV, et al. Skin graft pigmentation: a new approoach to prevention. Plast Reconstr Surg 1972;49:18- 21.
94. Kim JH, Kim KC. Principles of skin grafts. In: Plastic surgery secrets. Weinzweig J,ed. Hanley and Belfus, Inc. Philadelphia 1999;40814.
95. Evans GRD. Local flaps of the head and neck. In: Plastic surgery secrets. Weinzweig J,ed. Hanley and Belfus, Inc. Philadelphia 1999;185-193.
96. Peng VT, Sturm RL, Marsh TW. Pinch modification of the linear advancement flap. J Dermatol Surg. Oncol 1987;13:251-3.
97. Lambert RW, Dzubow LM. A dorsal nasal advancement flap for off-midline defects.J Am Acad Dermatol. 2004 Mar;50(3):380-3.
98. Flint ID, Siegle RJ. The bipedicle flap revisited. J Dermatol Surg Oncol 1994;20:394-400.
99. Keser A, Sensoz O, Mengi AS. Double opposing semicircular flap: a modification of Opposing Z-plasty for closing circular defects. Plast Reconstr Surg 1998;102:1001-7.
100. Jackson TI. General considerations. Jackson TI,ed. Local flaps in head and neck reconstruction. CV Mosby 1985;1-34.

101. Usatine RP, Moy RL, Tobinick EL: Elliptical excision. In: Skin Surgery. A Practical Guide. 1998:120-36.
102. Harrison PV.A guide to skin biopsies and excisions. Clin Exp Dermatol. 1980 Jun; 5(2): 235-43.
103. Raveh Tilleman T, Tilleman M.M, Krekels GAM and Neumann MHA. Skin waste, vertex angle and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, rhomboid, mosque and S-shaped. Plast Reconst Surg 2004;113:3:857-861.
104. Ashbell TS. The rhomboid excision and limberg flap reconstruction in difficult tense-skin areas.Plast Reconstr Surg. 1982 Apr; 69(4): 724.
105. Izaguirre H, Navarro C. Rhomboid-to-"W" technique for excision and closure of facial skin lesions. J Maxillofac Surg. 1983 Oct; 11(5): 207-10.
106. Mizunuma M, Yanai A, Tsutsumi S, Yoshida H, Seno H, Inoue M, Nishida M. Can dog-ear formation be decreased when an S-shaped skin resection is used instead of a spindle skin resection? A three-dimensional analysis of skin surgery techniques using the finite element method. Plast Reconstr Surg. 2000 Sep; 106(4): 845-8
107. Yoshida H, Tsutsumi S, Mizunuma M, Yanai A.Three-dimensional finite element analysis of skin suture. Part 1: spindle model and S-shaped modified model. Med Eng Phys. 2000 Sep; 22(7): 481-5.
108. Paolo B, Stefania R, Massimiliano C, Stefano A, Andrea P, Giorgio L.Modified S-plasty: an alternative to the elliptical excision to reduce the length of suture. Dermatol Surg. 2003 Apr; 29(4): 394-8.
109. Davis TS, Graham WP 3rd, Miller SH. The circular excision. Ann Plast Surg. 1980 Jan; 4(1): 21-4.
110. Skin and subcutaneous lesions. In: Plastic and reconstructive surgery, essential for students. Plastic Surgery Educational Foundation, Illinois 1979;18-30.
111. Marchac D. Techniques of surgical repair. In: Marchac D,ed. Surgery of basal cell carcinoma of the face. Spring-Verlag 1988;14.
112. Manstein CH, Manstein ME, and Manshtein G. Creating curvilinear scar. Plast Reconst Surgery 1988;83(5):914-5.
113. Borges AF. Unfavorable results in scar revision. In: Goldwyn RM, ed. The

unfavorable results in plastic surgery avoiding and treatment.Little Brown and Company, Boston,Toronto 1984;203-211.

114. Wheeland RG. Random pattern flaps. In: Roenigk RK, and Roenigk HH,eds. Dermatologic Surgery Principles and practice. Marcel Dekker Inc, New York, Basel 1988;265-273.
115. Maloney M. Basic skin surgery techniques. In: Harper j, Oranje A, and Prose N, eds.Textbook of pediatric dermatology. Blackwell Science Ltd 2000;28.1:1767-81.
116. Atlas of cutaneous surgery and basic excisional technique. In: Fewkes JL, Cheney ML and Pollack SV,eds. Illustrated atlas of cutaneous surgery. J.B.Lippincott Company. Philadelphia 1992;6.2-6.7.
117. Le surjets. In:Letessier S, Bachellier-Beuzelin Y, and Grognard C,eds. Manuel partique de chirurgie dermatologique. Masson, Paris 1986;35-38.
118. Indikationsabwagung bei der operativen therapie benigner hautveranderungen. In: Konz B, and Braun-Falco O,eds. Komplikationen in der operativen dermatologie. Springer-Verlag 1984;145.
119. Wundverschlub in dermatochirurgischen bereich. In: von B. Knoz H, and Burg G, eds.Dermatochirurgie in klinik und praxis. Springer-Verlag 1977;29-31.
120. Surgical techniques. In: Petres J, and Hundeiker M,eds. Dermatosurgery. Spring-Verlag 1978;42-45.
121. General considerations. In: Jackson TI,ed. Local flaps in head and neck reconstruction. CV Mosby 1985;1-34
122. Standardtechniken in der operativen dermatologie and Nahlappenplastiken. In: Kaufmann VR, and Landes E,eds. Dermatologische Operationen. George Thieme Verlag Stuutgart, New York 1987;22-3, 45.
123. Emergency room. In: Pletta FX,ed. Pediatric plastic surgery volume 1 Trauma. C.V. Mosby Company, Saint Louis 1967;5-20.
124. Chang WHJ. Wound management. In: Chang WHJ,ed. Fundamentals of plastic and reconstructive surgery. Williams and Wilkins, Baltimore London 1980;9-61.
125. Skin flaps. In: Padgett EC and Stephenson KL, eds. Plastic and reconstructive surgery. Charles C Thomas, Springfield Illinois ;18-40. YEAR!!
126. Facial scars. In:Fomon S,ed. Cosmetic surgery. Principles and practice.

J.B.Lippincott Company, Philadelphia Montreal 1960;134-160.

127. Wounds. In: Berson MI,ed. Atlas of plastic surgery. Grune and Stratton, New York 1948;3-54.
128. General technique of plastic operqations. In:Bankoff G,ed. Plastic surgery. Medical Publications Ltd, London 1943;45-62.
129. Barron JN, and Saad MN. An introduction to operative plastic and reconstructive surgery. In:Barron JN, and Saad MN,eds. Operative plastic and reconstructive surgery. Churchill Livingstone 1980;3-45.
130. Fundamental techniques. In:Mckinney P, and Cunningham BL,eds. Handbook of plastic surgery. Williams and Wilkins, Baltimore london 1981;15-25.
131. Closure of wounds. In: Burian F,ed. The plastic surgery atlas. Butterworths London Czechoslovak Medical Press Prague. 1967;19-32.
132. Linear scar revision techniques. In:Borges AF, ed. Elective incisions and scar revision. Little, Brown and company 1973;35-60.
133. Penn J, Brown LJ, Berry TB, Schulmeister SA, Roylance J and Ormerod CL..Fat loss. In: Penn J,ed. Brenthurst papers. Problems in eye lid and socket reconstruction. Witwatersrand University Press Johannesberg 1944:4-16.
134. Grabb WC. Basic techniques in plastic surgery. In: Grabb WC, and Smith JW, eds. Plastic surgery. A concise guide to clinical practice. Little, Brown and Company, Boston 1973;3-74.
135. Free skin grafts. In: Barsky AJ, Kahn S, and Simon BE,eds. Principles and practice of plastic surgery. McGraw-Hill Book Company 1964;34-62.
136. Scar revision. In: Georgiade GS, Riefkohl R, and Levin LS,eds. Georgiade plastic, maxillofacial and reconstructive surgery. Williams and Wilkins 1997;117.
137. Anatomy and physiology. In: Battle RJV,ed. Clinical surgery. Plastic surgery. Butterworths, London 1965;115.
138. Skin flaps and pedicles. In:Mclaughlin CR,ed. Plastic surgery. An introduction for nurses. Faber and Faber Limited London :49-57.
139. Primary repair. In:Mustarde JC,ed. Repair and reconstruction in the orbital region. A practice guide. Churchill Livingstone 1969;2-16.
140. Vistnes LM. Basic principles of cutaneous surgery. In:Epstein E, and Epstein E

Jr,eds. Skin Surgery. W.B.Saunders Company 1987;44-55.

141. Weisberg NK, Nehal KS, and Zide BM. Dog-ears: a review. Dermatol Surg 2000;26:363-370.
142. Zitelli JA. Tips for a better ellipse. J Am Acad Dermatol 1990;22:101-3.
143. Complex closure. In:Bennett RG,ed. Fundamentals of cutaneous surgery. The C.V. Mosby Company 1988;473-91.
144. Dunlavey E, and Leishin B. The simple excision. Dermatol Clinics 1998;16(1):49-64.
145. Ellipse. In: Stegman SJ, Tromovitch TA, and Glogau RG,eds. Basics of dermatologic surgery. Year Book Medical Publishers, Inc. Chicago, London 1982;60-8.
146. Mackay GJ, Carlson GW, and Bostwick J. Plastic and maxillofacial surgery. In: Sabiston DC,ed. Textbook of surgery seventh edition. WB Saunders company 1997;1298-33.
147. Wood RJ and Jurkiewicz. Plastic and reconstructive surgery. In: Schwartz SI, Shires GA, Spencer FC, Daly JM, Fischer JE, and Galloway AC, eds. Principles of surgery seventh editon. McGraw Hill 1999;2091-143.
148. Walker WF. Plastic surgery. In: Walker WF,ed. A colour atlas of minor surgery. Wolfe Medical Publications Ltd 1986;134-43.
149. Zuber TJ. Fusiform excision.Am Fam Physician. 2003;67:1539-44.
150. Pardasani AG, Leshin B, Hallman JR, White WL. Fusiform incisional biopsy for pigmented skin lesions.Dermatol Surg. 2000;26:622-4.
151. Miller LJ, Argenyi ZB, Whitaker DC. The preparation of frozen sections for micrographic surgery. A review of current methodology. J Dermatol Surg Oncol. 1993;19:1023-9.
152. Ishikawa T, Ishikawa O, Miyachi Y.Measurement of skin elastic properties with a new suction device (I): Relationship to age, sex and the degree of obesity in normal individuals. J Dermatol. 1995;22:713-7.
153. Cua AB, Wilhelm KP, Maibach HI. Elastic properties of human skin: relation to age, sex, and anatomical region.Arch Dermatol Res. 1990;282:283-8.
154. Weber PJ, Moody BR, Dryden RM, Foster JA. Mohs surgery and processing: novel optimizations and enhancements. Dermatol Surg. 2000;26:909-14.

155. De Giorgi V, Mannone F, Quercioli E, Giannotti V, Piccolo E, Carli P. Dog-ears: a useful artifice in the closure of extensive wounds. J Eur Acad Dermatol Venereol. 2003 Sep;17(5):572-4.
156. Pritchard GA, Zhang LJ, Hughes LE. Suture or graft? Changing trends in melanoma wound closure. Eur J Surg Oncol. 1988 Oct;14(5):371-7.

Table 1: Surgical cutting patterns: fusiform ellipse, fusiform circle, rhomboid, S-shape, mosque and circle.

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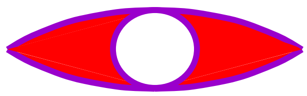
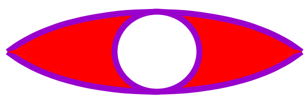
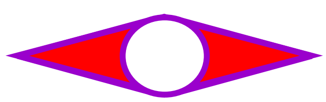
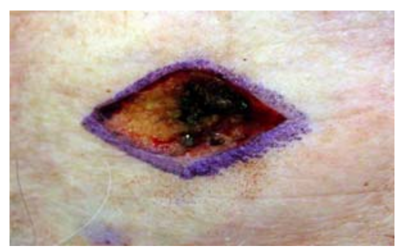
1	Fusiform ellipse		
2	Fusiform circle		
3	Rhomboid		

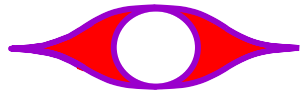
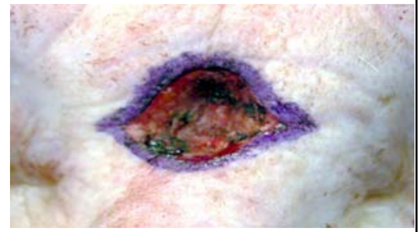
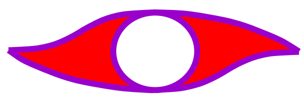
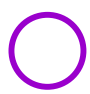
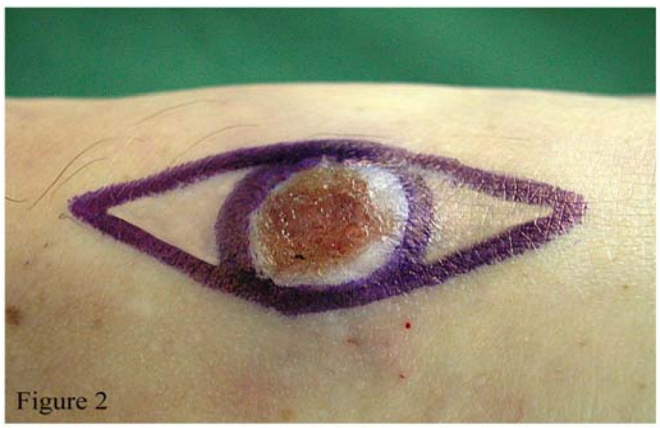
4	Mosque		
	Pattern	**Drawing**	**Photograph**
5	S-shaped		
6	Circular shape		

Figure 1



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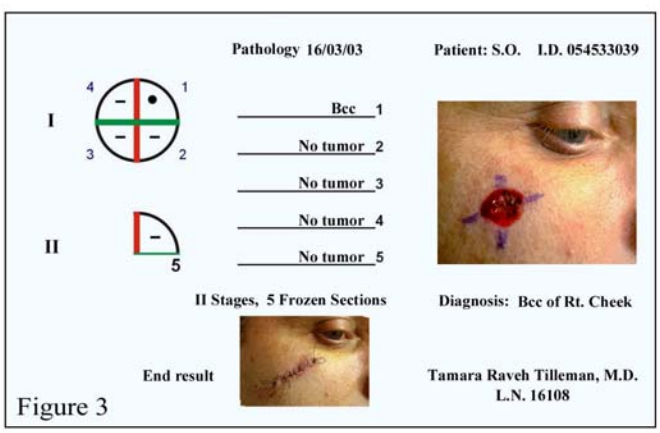

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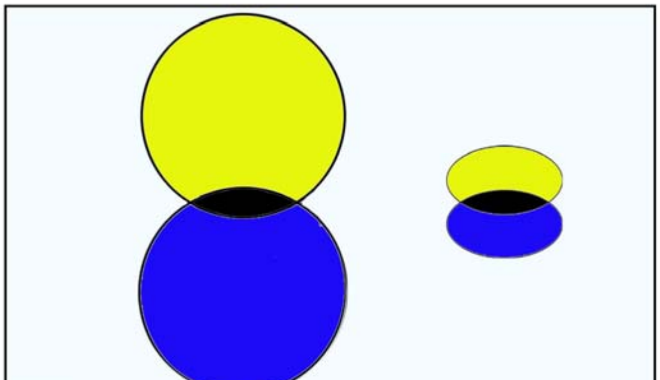

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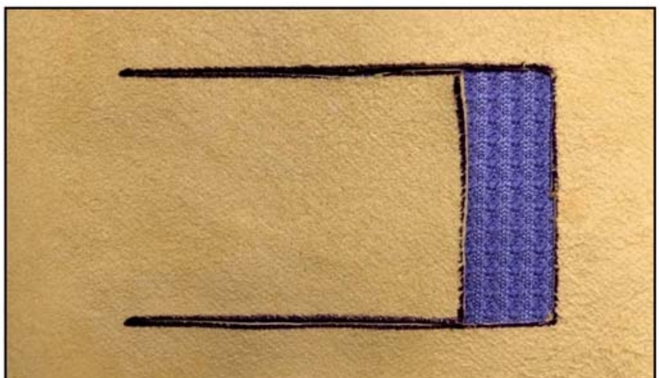

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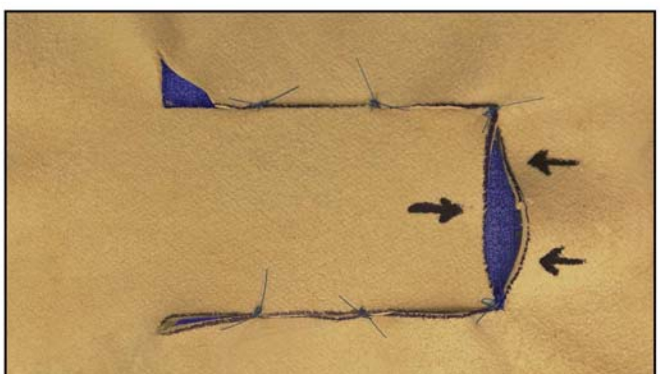
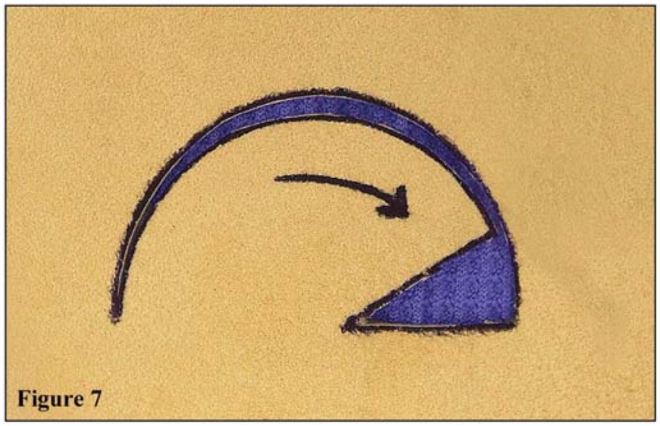


Figure 6



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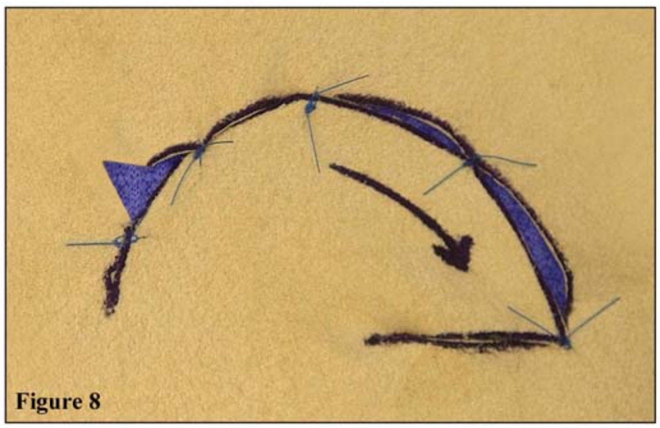

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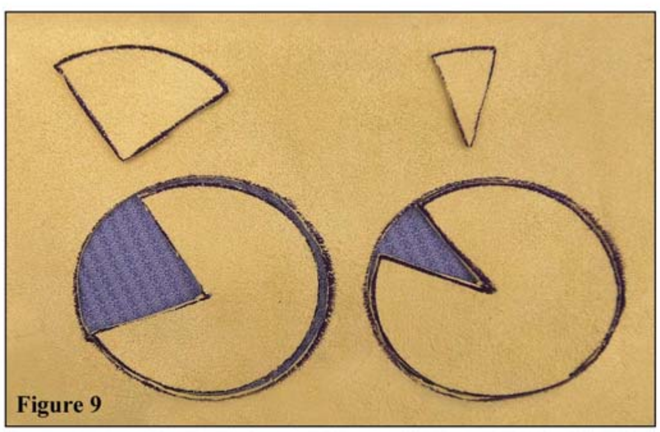
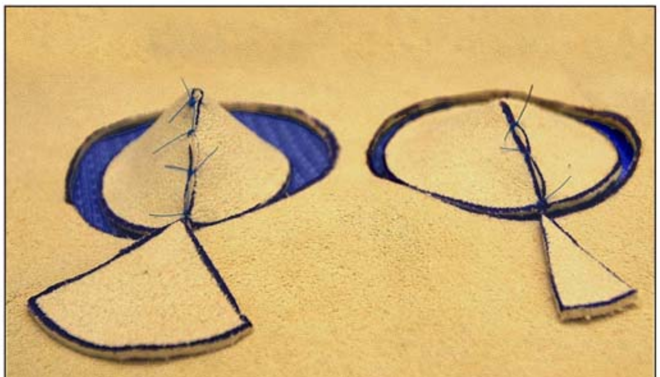


Figure 9

Figure 10



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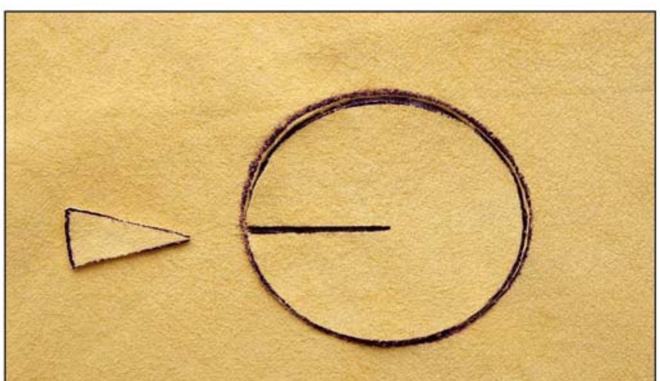
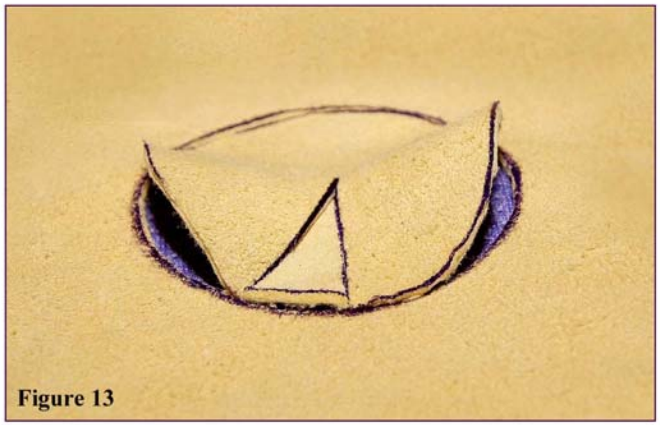


Figure 12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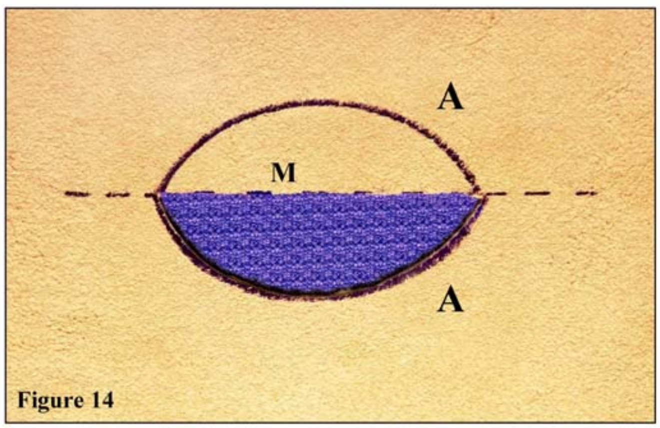

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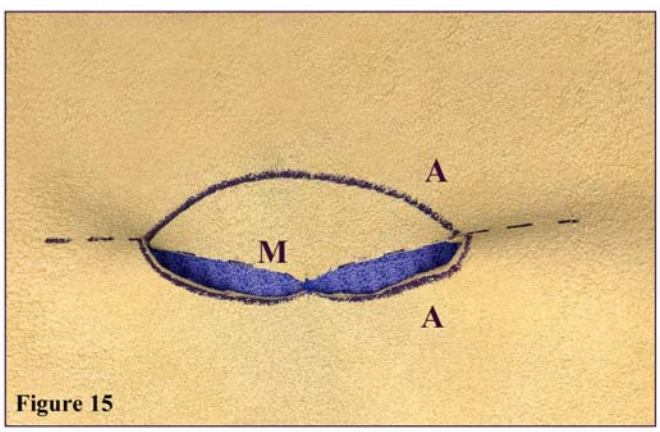

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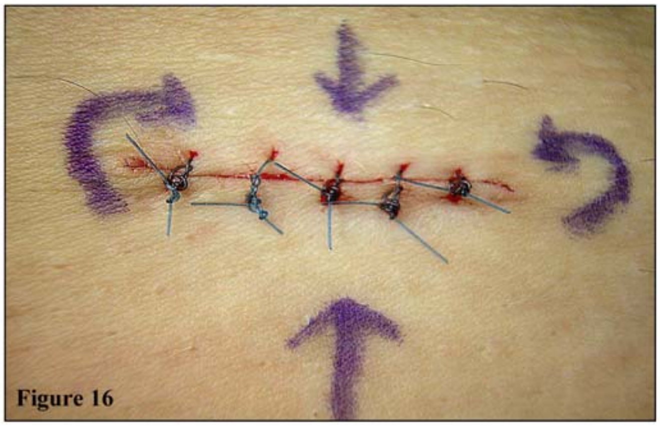

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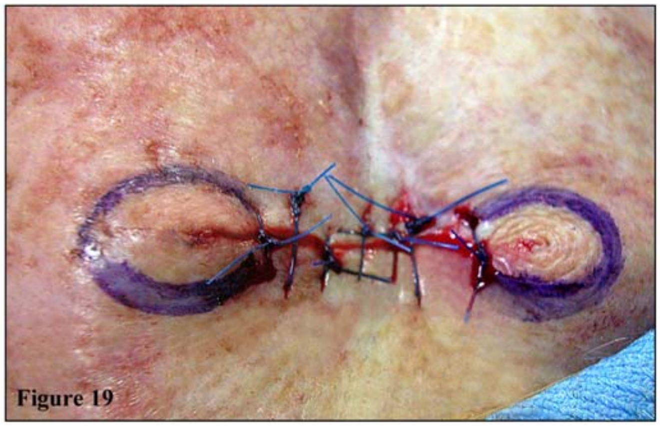

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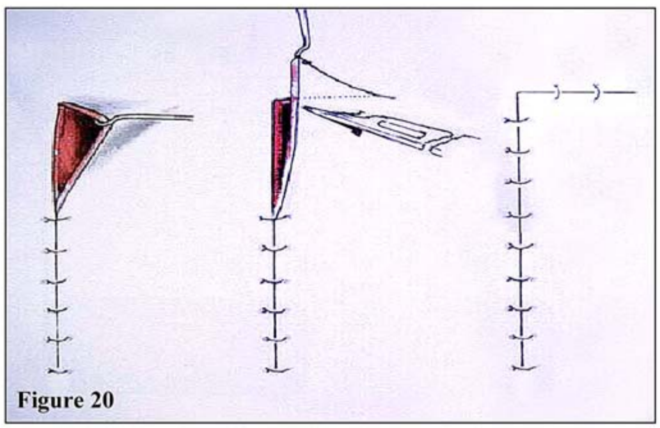
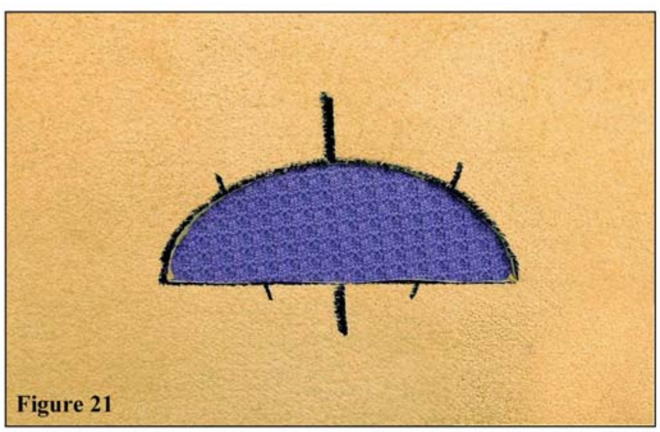


Figure 20



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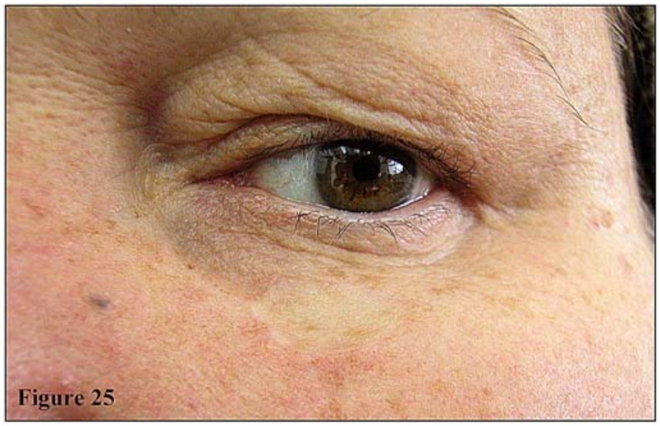
Figure 25


Figure 26


Figure 27

Chapter 2

Skin waste, vertex angle and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, rhomboid, mosque and S-shape.

Publication:

Raveh Tilleman T ,Tilleman MM ,Krekels GAM and Neumann HAM. Skin waste and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, diamond, mosque and S-shape. Plast Reconst Surg 2004:113:857-861.

Presentation:

- Combined annual meeting of the American Society for Dermatologic Surgery (ASDS) and the American College of Mohs Micrographic Surgery (ACMMSCO). New Orleans October 2003
- 2nd Annual Research Meeting. Rabin Medical Center, Petach Tikva ,Israel, November 2003.
- 29th Annual Israel Plastic Surgery Meeting. Tel Aviv, Israel, November 2002.

Abstract

The common excision skin pattern is either a fusiform ellipse or another pattern with dissimilar length and width. The purpose of this study is to define the most advantageous skin pattern in regard to skin waste, vertex angle and scar length. Five various skin excision patterns used traditionally for closure of round lesions were analyzed: 1) fusiform ellipse, 2) fusiform circle, 3) rhomboid, 4) mosque and 5) S-shape. In the analysis we formulated the pattern characteristics by geometrical principles, from which the results were compared. The smallest skin waste was found in rhomboid and mosque patterns, while the largest skin waste was found in the fusiform circle and ellipse. The vertex angle was found to decrease monotonously with the excision length-to-width ratio for all patterns except for the mosque shape, which is zero per definition. The paradigm stating that a vertex angle of 30º or less is maintained for length-to-width ratios below 4 in surgical ellipse was found incorrect. It holds only for rhomboid and S-shaped excisions. The scar length was found almost independent of the pattern, with a variance of 3%. We conclude that the most advantageous surgical skin patterns are the rhomboid and mosque excisions.

Introduction

In the field of plastic cutaneous surgery the objective is to obtain an esthetical and functional result. Skin scars resulting from the removal of skin lesions need be designed with a minimal scar length, minimal healthy tissue waste, well oriented scar, confinement to a single cosmetic unit and no damage to tissue function (1,2).

Many skin lesions are circular, yet the final excision pattern has a larger area and is elongated. An elliptical shape or any other pattern with an unequal width and length is commonly used. These patterns allow primary closure without tissue protrusion and dog-ear formation (3). As a general rule, a length-to-width ratio between 3:1 to 4:1 is recommended (4,5). This results in longer scars compared to the original round lesion but impedes tissue bunching up at the vertices (6). In the most common skin excision pattern, the fusiform ellipse, the skin waste can exceed the original lesion area by hundreds percent (7).

The purpose of this study is to define the most advantageous skin pattern by means of geometrical analysis. Our criteria in defining such optimum are: 1) minimum skin waste, 2) narrow vertex angle, and 3) the shortest scar.

Materials and Methods

A geometrical analysis of five various skin excision patterns wad studied:

1. Fusiform ellipse, tangent to the round lesion,
2. Fusiform circle, tangent to the round lesion,
3. Rhomboid, contained by lines tangent to the round lesion,
4. Mosque, modeled as sinusoidal lines containing the lesion, and
5. S-shape, modeled as a combination of circle arcs and mosque lines.

Though the first two patterns in the table seem similar they are not strictly identical, as explained in the formulae and results below.

From basic geometrical principles, the above pattern areas, vertex angles and scar lengths are mathematically formulated. In the following the pattern areas are expressed:

Fusiform ellipse: is defined by the area overlapped by two fused ellipses. Its area is:

$$A = \frac{S^2 a}{2}\left\{\sqrt{\frac{at-2}{at}}\left(\frac{at-1}{at-2}\right)^2 \sin^{-1}\left[\frac{\sqrt{at(at-2)}}{at-1}\right] - \frac{1}{at-2}\right\} \tag{1}$$

where; *S* is the width of the fusiform ellipse, *a* is the length-to-width ratio, and t is the tangent of the half vertex-angle:

$$t = \tan\left(\theta/2\right)$$

Fusiform circle: is a special case of a fusiform ellipse where the two forming shapes are circles. The vertex angle is determined by the length-to-width ratio:

$$\theta = 2\tan^{-1}\left[2a/\left(a^2-1\right)\right]$$

By substituting this angle in equation (1) one obtains:

$$A = \frac{S^2}{8}\left[\left(a^2+1\right)^2 \sin^{-1}\left(\frac{2a}{a^2+1}\right) - 2a\left(a^2-1\right)\right] \tag{2}$$

Rhomboid shape: is defined by lines tangent to the round lesion stretching to two vertices. Its area is expressed by:

$$A = \frac{S^2}{2}\left(\sqrt{a^2-1} + \sin^{-1}\frac{1}{a}\right) \tag{3}$$

Mosque pattern: is modeled based on a sinusoidal line tangent to the round lesion.

It is formulated as:

$$y = \frac{r}{2}\left(1 + \cos\frac{\pi}{ar}x\right) \tag{4}$$

where: x and y are the abscissa and the ordinate originating at the circle center, r is the radius of the round lesion, and a is the length-to-width ratio. Assuming that the entire width is 2r, or S = 2r, then by integrating over the length one finds the area:

$$A = \frac{S^2}{2}a \tag{5}$$

S-shape excision: is modeled as half mosque and half-fusiform circle, so its area is the average of the areas given in equations (2) and (5).

We define skin waste as the difference between the area of the pattern and the round lesion. Thus, from the above formulated areas we subtracted the area of the round lesion πr^2. Note that had the excision equaled the round lesion itself, the skin waste would be identically zero.

Table 1 includes formulae of vertex angles expressed by the length-to-width ratio and the formulae of the arc lengths (or perimeters). The vertex angles are individual to each pattern, some of which are described below.

The fusiform ellipse vertex angle expressed by the length-to-width ratio is:

$$\theta_E \geq 2\tan^{-1}\left(\frac{2}{a}\right)$$

Inferred from the inequality in the vertex-angle formula, there are many fusiform ellipses that fit a given length-to-width ratio. They can be characterized by the distance between the major axes of their forming ellipses. Their vertex angles range between $2\tan^{-1}(2/a)$ and 180º. Though we calculated several examples of fusiform ellipses only a single such ellipse was chosen. Its forming ellipses lie from one another at a distance equaling five times the lesion diameter. The vertex-angle of the mosque shape is identically zero. The vertex-angle of the S-shape is the average of the angles of the fusiform circle and the mosque shape, making it half the vertex angle of the fusiform circle.

The perimeter formula is obtained by integrating the pattern line over the pattern length. Also in Table 1, given is the scar length, expressed by a product of the perimeter and a factor adapted from Mizunuma et al (8).

Results

Figure 1 shows the ratio of skin waste-to-lesion area for the various patterns. Skin waste is defined as the net area of the excision calculated from each pattern formula, for instance equations 1, 2, 3 and 5, and the round lesion area. The smallest waste is found for rhomboid and mosque patterns, while the largest waste is found for the fusiform circle and ellipse. The median waste is found for the S-shape, which is a mid-way pattern between the fusiform circle and the mosque patterns. This trend is quite expected owing to our geometrical definition of the S-shape model. For the common length-to-width ratio range of 3 – 4 the skin waste is 90% - 245%. One can also observe from the figure that the skin waste is proportional to the length-to-width ratio for all the shapes. Note that had a circular cut been considered, its waste area would be zero.

Figure 2 shows the vertex angle of the various patterns. The angle decreases monotonously with the excision length-to-width ratio for all patterns except for the mosque shape. For a surgical ellipse, the most common excision shape, we calculated vertex angles between 44º - 74º and 33º - 56º, respective to length-to-width ratios of 3 and 4. The vertex-angle range reflects the distance between the major axes of their forming ellipses as was explained in the previous section. Note that the vertex angle of 30º within the range of length-to-width ratio of 3 to 4 holds for only the rhomboid and S-shapes.

Figure 3 plots the scar length as a function of the length-to-width for all the patterns. The scar length is proportional to the excision perimeter, such that it equals 96% of half the perimeter for the S-shaped pattern, and 92% for all other patterns: fusiform ellipse, fusiform circle and mosque. We assumed a similar change for a rhomboid pattern as well. These proportions have been adapted from Mizunuma et al (8). We found that the scar length is nearly proportional to the lesion radius and the length-to-width ratio, and almost independent of the pattern. What stands out is that the scar is typically longer than the lesion diameter by a factor approximately the length-to-width ratio. Therefore, one can predict the scar length of any surgical pattern knowing only its length and width (equaling the lesion diameter). According to this rational a circular cut would result in the shortest possible scar.

Table 2 summarizes the results for the five excision patterns in terms of waste area, vertex angle and scar length. The results are given for a length-to-width ratio of 4. The excess skin waste is calculated as the ratio of the areas of the net excision pattern to the circular lesion. Observe that the least skin waste is obtained for the rhomboid and mosque excisions, for which also the vertex angles are the smallest. The scar length depends linearly on the lesion diameter, and is approximately the same for all the patterns.

Discussion

The final excision pattern of cutaneous lesion is usually elliptical. New patterns are being suggested to exchange that tradition of choosing the elliptical excision. This article tries to find the most economical pattern concerning extra skin waste and scar length. First compared are the excision skin-waste areas. Strictly from the standpoint of minimum waste area, the superior approach is to perform a rhomboid or mosque excision. If, for instance, one selects the length-to-width ratio of 3 – 4 then the skin waste is 90% - 160% in excess of the original round lesion, for the mosque and rhomboid shape, and up to 245% for the fusiform ellipse or fusiform circle.

Second comparison is of vertex angles. The angle decreases with the excision length-to-width ratio for all patterns. Yet, the current paradigm maintaining that the vertex angle should be 30° or less for length-to-width ratios below 4 is incorrect. Only rhomboid and S-shapes can produce such narrow angles while other patterns, those of fusiform ellipse and circle exhibit a vertex angle of up to 60°. A large vertex angle therefore creates stress on the skin during suturing rendering unfavorable conical deformations resulting in dog-ears, as postulated by Limberg in 1966 (1). Note that while performing an excision with a small angle is desirable, the mosque shape with a zero vertex angle presents surgical and technical difficulties.

It is noteworthy that a circular excision pattern, i.e. a direct excision of the round lesion, creates no skin waste and results in the shortest scar length. On the other hand a circular excision possesses the greatest vertex angle (180°) thus creating huge dog-ears during closure and a bad scar.

The next chapter examines the theoretical results of the fusiform ellipse treated in this chapter vis a vis clinical data.

References

1. Limberg AA. Design of local flaps. In: Gibson T,ed. Modern trends in plastic surgery. Butterworth & Co. London;1966:38-61.
2. Leshin B. Proper planning and execution of surgical excisions. In: Wheeland RG,ed. Cutaneous surgery. W.B.Saunders company;1994:171-177.
3. Borges AF. Dog ear repair. Plast Reconst Surgery;1982:69(4):707-13.
4. Dunlavey E and Leshin B. The simple excision. Dermatol Clinics. 1998;16(1):49-64.
5. Bennett RG. Complex closures. In: Bennett RG, ed. Fundamentals of cutaneous surgery. C.V. Mosby Company;1988:473-491
6. Rohrich RJ and Robinson. Wound closure. In: Rohrich RJ and Robinson, eds. Wound healing. Selected redings in plastic surgery. University of Texax southwestern medical center and Bayelor University medical center;1999:9(3):18-20.
7. Raveh Tilleman T, Smeets N, Tilleman M.M, and Neumann HAM. Skin waste in elliptical excision biopsies . Accepted to the Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery.
8. Mizunuma M, Yanai A, Tsutsumi S, Yosida H, Seno H, Inoue M, and Nisbida M. Can dog ear formation be decreased when an s shape resection is used instead of spindle skin resection? A three dimensional analysis of skin surgery techniques using finite element method. Plast Reconstr Surg. 2000;106(4):845-8.

Table 1: Formulae of vertex angles and scar length of five excision patterns.

	Shape	Formula of Vertex Angle	Formula of Scar Length	
			Arc Length	Factor
1	Fusiform ellipse	$\theta_E \geq 2\tan^{-1}\left(\frac{2}{a}\right)$	$L = \int_{-aS/2}^{aS/2} \sqrt{\frac{1-k^2\left(x/\alpha\right)^2}{1-\left(x/\alpha\right)^2}}dx$	0.92
2	Fusiform circle	$\theta = 2\tan^{-1}\left[2a/\left(a^2-1\right)\right]$	$L = \int_{-aS/2}^{aS/2} \frac{dx}{\sqrt{1-\left(x/R\right)^2}} = S\left(1+a^2\right)\sin^{-1}\frac{a}{1+a^2}$	0.92
3	Rhomboid (diamond)	$\theta = 2\sin^{-1}\left(1/a\right)$	$L = S\left(\sqrt{a^2-1}+\sin^{-1} 1/a\right)$	0.92
4	Mosque	0	$L = \int_{-aS/2}^{aS/2} \sqrt{1+\left(\frac{\pi}{2a}\right)^2 \sin^2\frac{\pi}{ar}}dx$	0.92
5	S-shape	Half of No.2	Average of No.2 and 4	0.96

Table 2: Summarized results for the five excision patterns by the three criteria. The results are given for a length-to-width ratio of 4. The excess skin waste is the difference between the areas of the excision pattern and the round lesion.

	Shape	Length-to-width ratio	Arc length (cm)	Excess skin waste	Vertex angle (degree)	Scar length (cm)
1	Fusiform ellipse	4	4.18	245%	33º	3.85
2	Fusiform circle	4	4.16	244%	56º	3.83
3	Rhomboid	4	4.13	162%	28º	3.80
4	Mosque	4	4.18	155%	0º	3.82
5	S-shape	4	4.16	200%	28º	3.99

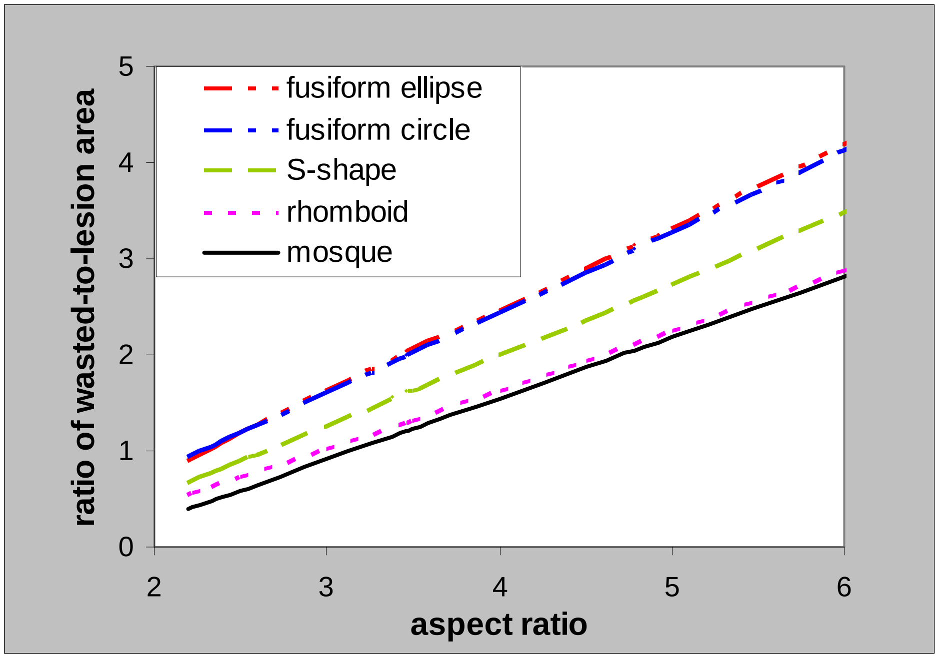

Figure 1: Ratios of wasted areas to round lesion areas.

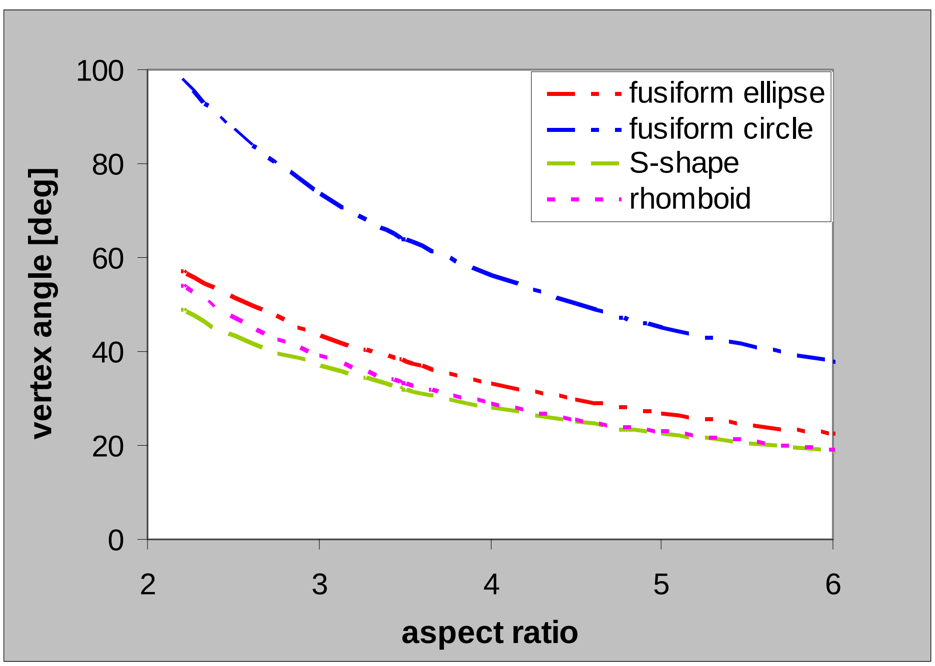

Figure 2: Vertex angle as a function of the length-to-width ratio.

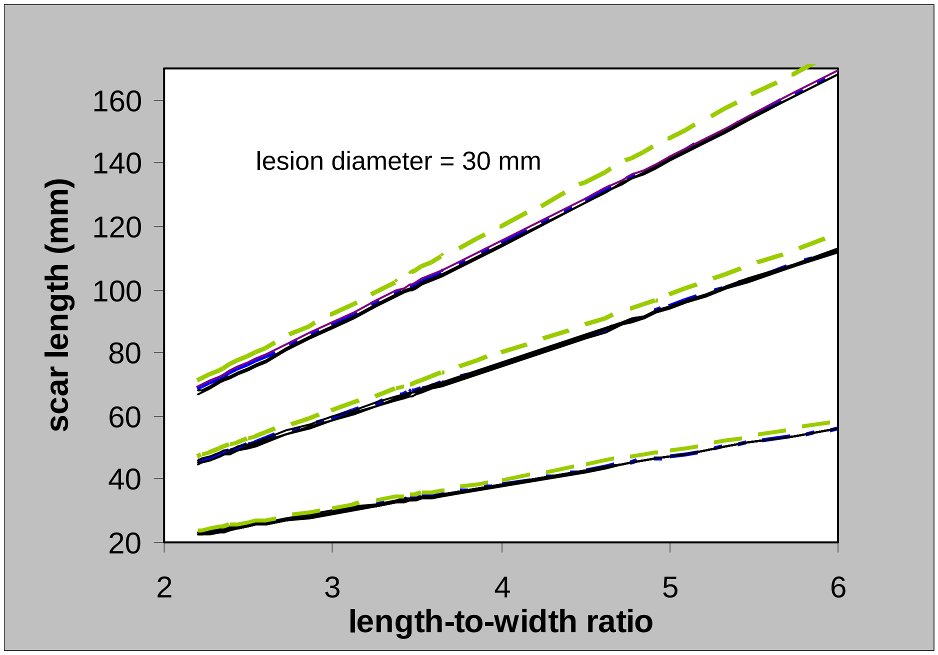

Figure 3: Scar length as a function of the length-to-width ratio. The parameter is the lesion diameter, depicted at 10, 20 and 30 mm. The S-shape is represented by the broken lines, whereas all the other shapes overlap being denoted by the solid line.

Chapter 3

Evidence Based Surgery: The paradigm of surgical ellipse length-to-width ratio and vertex angle.

Publication:

Raveh Tilleman T ,Tilleman MM,and Neumann HAM. Evidence Based Surgery: The paradigm of surgical ellipse dimensions: relation of length-to-width ratio and vertex angle. Submitted to: Br J Plast Surg 2004.

Abstract

The paradigm concerning the dimensions of a surgical ellipse is examined. To date it has been postulated that elliptical excisions must possess a length-to-width ratio of 3:1 to 4:1 and a vertex angle of 30º or less in order to be closed primarily without creating a "dog-ear". These dimensions became axiomatic in teaching cutaneous surgery. The present article examines the validity of this paradigm.

We collected data from two sources: published ellipses in plastic, general and dermato - surgery literature (fifty seven cases) and elliptical excisions performed at the authors' outpatient clinic (eighty three cases). The surgical ellipse lengths, widths and vertex angles were analyzed, setting an empirical law. Then, the data were compared with a calculation based on a mathematical formula of a fusiform ellipse.

The results showed that the length-to-width ratio of 3:1 – 4:1 is inconsistent with the vertex angle of 30º. To meet this length-to-width ratio a surgical ellipse must posses a vertex angle of 63º – 48º, respectively.

In conclusion the paradigm that the surgical ellipses have a vertex angle of 30º within the said range of length-to-width ratios is incorrect. The vertex angles are appreciably larger, as predicted by the evidence-based approach. These results have important implications in cutaneous surgery both on the skin waste and on the scar length.

Introduction

The objective of all physicians is to provide their patients with the best health care. To do so a physician is trained for years and undergoes a long residency during which he or she learn to diagnose patients as well as to treat and try to prevent diseases. Clinical training of residents is based on an apprenticeship model in which the residents learn medicine and surgical techniques from experienced attending doctors. The current apprenticeship model of clinical training perpetuates bad habits including: preserving the present hypothesis for the diseases etiology, pathology and treatment, patient treatment based on personal experience or nonsystematically collected results and treatment bias toward the newest methods presented (1). The apprenticeship model is experience-based medicine, being gradually substituted by evidence-based medicine (EBM) (2). In practicing EBM, the need for information is converted into a question answered by the current best evidence resources such as textbooks and electronic databases. This information is integrated with the clinical expertise. The principles of EBM were developed by physicians and epidemiologists for both teaching medical students and helping physicians in using the best and most up-to-date evidence in order to make decisions about their patient care. (3)

Evidence Based Medicine became the golden standard in practicing medicine (4), whereas Evidence Based Surgery is lagging behind the scientific evidence (5). In addition, the surgical literature is poor in highly valuable evidence in comparison with the general medical literature (6). The reasons for such discrepancy include the fact that not all surgical procedures are suitable for trials, patients fear of practicing in surgical trails, difficulty to standardize surgical treatment as opposed to medicine, the lack of surgeons' enthusiasm to participate in clinical trials, and last, the funding of surgical trials are often difficult to obtain (7).

In this evidence-based-surgery study we explore the most common technique used for removing skin lesions, the surgical ellipse (8-10). This shape, also known as a fusiform ellipse, is the overlapped zone of two ellipses thus producing two vertices. The paradigm of cutaneous-cut dimensions relating the length-to-width ratio to the vertex angle of a surgical ellipse excision is examined. To date it has been postulated that elliptical excisions must possess a length-to-width ratio of 3:1 to 4:1 and a vertex angle of 30º or less in order to be closed primarily without creating a "dog-ear" (11-19). These dimensions became axiomatic in surgery, taught in apprenticeship model for a few generations. The present article questions the validity of this paradigm by measuring and calculating the exact dimensions of a surgical ellipse: length-to-width ratio and vertex angle.

Method

In an attempt to find the underlying rule relating the vertex angle to the length-to-width ratio we analyzed two data sets: 1. Fifty seven surgical ellipses published in the literature, 2. Eighty three surgical ellipses excised at our outpatient, and a calculation based on a mathematical formula. The data were compared with each other and with the calculation.

We collected data from published ellipses in plastic surgery, general surgery and cutaneous surgery literature. Books and articles from the private library of a plastic surgeon (first author), a dermato-surgeon (last author), the library of the plastic surgery department, the medical library of the hospital Academisch Ziekenhuis Maastricht and Medline research results were reviewed. Forty one references presented drawings or photographs of surgical ellipses (20-61). Extracted from them are fifty seven ellipses, fifteen of which are photographed in vivo and the remainder are graphically drawn ellipses. We also collected consecutive data of eighty three surgical ellipses performed at the authors' outpatient clinic.

The data were compared with a calculation of a fusiform ellipse vertex angles, expressed by the following formula (62):

$$\theta_E \geq 2\tan^{-1}\left(\frac{2}{a}\right)$$

where a is the length-to-width ratio. By comparing the clinical ellipses to the formula an empirical law was set for the length, width, length-to-width ratio and vertex angle.

Results

The ellipse dimensions of the compiled data from references 20 – 61 are summarized in Table 1. Their vertex angles are plotted against the length-to-width ratio in Figure 1. The ellipse dimensions of our clinical data are summarized in Table 2. Their vertex angles are plotted against the length-to-width ratio in Figure 2. Included in both figures are the plots of the theoretical vertex angles calculated by the above equation, denoted by the pink line.

In Figure 1 the reviewed length-to-width ratio varies between 1.7 and 6.2, and the vertex angle varies between 32.5º and 110º, with a measurement error of ±2.5º. Assuming a power regression curve the vertex angle is typified by $\theta_{DATA} = 128.7a^{-0.71}$ where a is the length-to-width ratio, with $R^2 = 0.48$. In Figure 2 the length-to-width ratio of the clinical ellipses varies between 1.3 and 6.3, and the vertex angle varies between 42.5º and 118º, with a measurement error of ±1º. In both figures we used as vertex angle the average of the two vertices. Assuming a power regression curve the vertex angle is typified by $\theta_{DATA} = 125.5a^{-0.71}$, with $R^2=0.82$. Both power regression curves are very similar, setting an empirical law to this relation. These curves, however, are somewhat removed from the theoretical fusiform ellipse, for the reason that the surgical ellipse is hardly ever a simple, canonical geometrical pattern. Note, that our original data scatter is significantly smaller than the data from the literature. We explain this by the fact that a single surgeon excisions and measurements are inherently more uniform than data from multiple sources.

Observe that the vast majority of the data have angles approaching those of a theoretical fusiform ellipse. In contrast, it is necessary to stress out that in the literature and in our clinical data the angle corresponding to the length-to-width ratio between 3:1 and 4:1 features best-fit angle values of θ_{DATA} = 58º to 48º (Figure 1) and 59º to 47º (Figure 2), respectively.

None of the data matches the paradigm of a 30º angle for a length-to-width ratio of 3:1 – 4:1. Note that the angle of 30º, axiomatically used in the literature, corresponds only to the aspect ratio of 7.5. Table 3 summarizes the vertex angles obtained for the length-to-width ratios of 3:1 and 4:1. In all, they span the range from 67º to 48º.

Discussion

High level available evidence in surgical literature is less abundant the in the general medical literature (6). The gold standard in EBM is the randomized controlled trial (RCT). Only 0.3% – 6% of the references in the surgical literature are RCTs (63). Given that RCTs are rarely performed in surgery, case studies are the majority of the surgical literature (64). This work is a case-control study with a systematic review.

The case used in this chapter is of a common, widely used procedure in surgery, the elliptical excision. The relation between the vertex angle of an ellipse and its length-to-width ratio has become axiomatic. By following the literature and by analyzing eighty three cases of clinical ellipses, then comparing them to a calculation based upon geometrical principles, we show the relation of the surgical-ellipse vertex-angle to the length-to-width ratio. What is proved is that within the commonly used range of length-to-width ratio of 3:1 to 4:1, the vertex angle is between 67º to 48º, never reaching the postulated value of 30º. Consistently, the 30º angle can be only reached for large length-to-width ratios, in excess of 7.5. It is also shown that the length to width ratio of 4:1 is rarely used in excisional biopsies and usually the aspect ratio is shorter, reaching an average of 3.1 in the published literature and 2.5 in the clinical data. The above results agree with a previous analysis covering a part of the theory on the apical angle (65) and with previously presented empirical data of length-to-width ratios in measured surgical ellipses (66) (see Chapter 5). These results have important implications on the skin wasted in cutaneous surgery and on the scar length. The smaller the length-to-width ratio and the greater the vertex angle, the smaller is the skin waste and the shorter is the scar length.

By using evidence based medicine, the question of what are the accurate dimensions of surgical ellipses was answered by the current best evidence resources. This information was integrated with our clinical experience. As many scientific theories in general, also medical paradigms should be questioned, tested, analyzed and verified by medical empirical findings. By doing so correct paradigms will prevail, while erroneous theorems will be disqualified and replaced.

References

1. Bigby M. Paradigm lost. Arch Dermatol 2000;136:26-7.
2. Evidence-Based-Medicine working group. Evidence-Based-Medicine: a new approach to teaching the practice of medicine. JAMA 1992;268:2420-5.
3. Sackett DL, Straus SE, Richardson WS, Rosenberg W, Haynes RB. Evidence-based Medicine: how to practice and teach EBM.1st Ed. New York: Churchill Livingstone, 1997.
4. Braunwald E, Fauci AS, Kasper DL, Hauser SL, Longo DL, Jameson JL Introduction to clinical medicine. In: Braunwald E, Fauci AS, Kasper DL, Hauser SL, Longo DL, Jameson JL, eds. Harrison's principles of internal medicine, 15th edition. McGraw-Hill. New York 2001;1-5.
5. Young JM, Hollands MJ, Wared J, Holman CDJ. Role for opinion leaders in promoting Evidence Based Surgery. Arch Surg 2003;138:785-91.
6. Offer GJ, Perks AGB. In search of evidence-based-plastic surgery: the problems faced by the specialty.
7. Beahrs OH. Clinical trails from the surgeon's view. Cancer 1990;65:2383-4.
8. Jankauskas S, Cohen IK, and Grabb WC. Basic Techniques of plastic surgery. In: Grabb WC, and Smith JW, eds. Plastic surgery. Little, Brown and Company 1991;3-90.
9. Mackay GJ, Carlson GW, Wood RJ, Bostwick J IIII. Plastic and maxillofacial surgery. In: Sabiston DC, Lyeryl HK, eds. Textbook of surgery. WB Saunders company 1997; 1298-1305.
10. Swanson NA and Gerkin RC. Recognition and treatment of skin lesions. In: Cummings CW, Fredrickson JM, Harker LA, Krause CJ,and Schuller DE, eds. Otolaryngology, head and neck surgery. Mosby Year Book, Inc. 1993;315-32.
11. McCarthy JG. Introduction to plastic surgery. in: McCarthy JG, ed. Plastic surgery. W.B. Saunders Company 1990;1-54.
12. McGregor IA. Wound care, and flaps, pedicle and tubes. In: McGregor IA, ed. Fundamental techniques of plastic surgery and their surgical applications. E & S Livingstone Ltd. Edinburgh and London 1960;3-39, 39-141.
13. Dermatological surgery. In: Champion RH, Burton JL, Burns DA, Breathnach SM.

Textbook of dermatology. Blackwell Science ltd. Oxford 1998;3602-5.
14. Hughes NC. Excision of tumors with direct closure of defect. In: Operative surgery. Fundamental international techniques. Butterworths 1979;12-3.
15. Dzubow LM. The dynamics of dog ear formation and correction, J Dermatol Surg Oncol 1985;11:722-8.
16. Robertson DB. Dog ear repair. In: Wheeland RG, ed. Cutaneous surgery. W.B.Saunders Company, 1994;295-303.
17. Dog ear repair. In: Rompel JPR,ed. Operative dermatologie. Lehrbuch und atlas. Springer 1996;54-55.
18. Complex excision. In: Fewkes JL, Cheney ML and Pollack SV, eds. Illustrated atlas of cutaneous surgery. J.B. Lippincott Company. Philadelphia 1992;16.1-16.8.
19. Limberg AA. Design of local flaps. In: Gibson T,ED. Modern trends in plastic surgery. Butterworth & co. London. 1966;38-61.
20. Skin and subcutaneous lesions. In: Plastic and reconstructive surgery, essential for students. Plastic Surgery Educational Foundation, Illinois 1979;18-30.
21. Marchac D. Techniques of surgical repair. In: Marchac D,ed. Surgery of basal cell carcinoma of the face. Spring-Verlag 1988;14.
22. Manstein CH, Manstein ME, and Manshtein G. Creating curvilinear scar. Plast Reconst Surgery 1988;83(5):914-5.
23. Borges AF. Unfavorable results in scar revision. In: Goldwyn RM, ed. The unfavorable results in plastic surgery avoiding and treatment.Little Brown and Company, Boston,Toronto 1984;203-211.
24. Wheeland RG. Random pattern flaps. In: Roenigk RK, and Roenigk HH,eds. Dermatologic Surgery Principles and practice. Marcel Dekker Inc, New York, Basel 1988;265-273.
25. Maloney M. Basic skin surgery techniques. In: Harper j, Oranje A, and Prose N, eds.Textbook of pediatric dermatology. Blackwell Science Ltd 2000;28.1:1767-81.
26. Atlas of cutaneous surgery and basic excisional technique. In: Fewkes JL, Cheney ML and Pollack SV,eds. Illustrated atlas of cutaneous surgery. J.B.Lippincott Company. Philadelphia 1992;6.2-6.7.
27. Le surjets. In:Letessier S, Bachellier-Beuzelin Y, and Grognard C,eds. Manuel

partique de chirurgie dermatologique. Masson, Paris 1986;35-38.

28. Indikationsabwagung bei der operativen therapie benigner hautveranderungen. In: Konz B, and Braun-Falco O,eds. Komplikationen in der operativen dermatologie. Springer-Verlag 1984;145.
29. Wundverschlub in dermatochirurgischen bereich. In: von B. Knoz H, and Burg G, eds.Dermatochirurgie in klinik und praxis. Springer-Verlag 1977;29-31.
30. Surgical techniques. In: Petres J, and Hundeiker M,eds. Dermatosurgery. Spring-Verlag 1978;42-45.
31. General considerations. In: Jackson TI,ed. Local flaps in head and neck reconstruction. CV Mosby 1985;1-34
32. Standardtechniken in der operativen dermatologie and Nahlappenplastiken. In: Kaufmann VR, and Landes E,eds. Dermatologische Operationen. George Thieme Verlag Stuutgart, New York 1987;22-3, 45.
33. Emergency room. In: Pletta FX,ed. Pediatric plastic surgery volume 1 Trauma. C.V. Mosby Company, Saint Louis 1967;5-20.
34. Chang WHJ. Wound management. In: Chang WHJ,ed. Fundamentals of plastic and reconstructive surgery. Williams and Wilkins, Baltimore London 1980;9-61.
35. Skin flaps. In: Padgett EC and Stephenson KL, eds. Plastic and reconstructive surgery. Charles C Thomas, Springfield Illinois ;18-40. YEAR!!
36. Facial scars. In:Fomon S,ed. Cosmetic surgery. Principles and practice. J.B.Lippincott Company, Philadelphia Montreal 1960;134-160.
37. Wounds. In: Berson MI,ed. Atlas of plastic surgery. Grune and Stratton, New York 1948;3-54.
38. General technique of plastic operqations. In:Bankoff G,ed. Plastic surgery. Medical Publications Ltd, London 1943;45-62.
39. Barron JN, and Saad MN. An introduction to operative plastic and reconstructive surgery. In:Barron JN, and Saad MN,eds. Operative plastic and reconstructive surgery. Churchill Livingstone 1980;3-45.
40. Fundamental techniques. In:Mckinney P, and Cunningham BL,eds. Handbook of plastic surgery. Williams and Wilkins, Baltimore london 1981;15-25.
41. Closure of wounds. In: Burian F,ed. The plastic surgery atlas. Butterworths London

Czechoslovak Medical Press Prague. 1967;19-32.
42. Linear scar revision techniques. In:Borges AF, ed. Elective incisions and scar revision. Little, Brown and company 1973;35-60.
43. Penn J, Brown LJ, Berry TB, Schulmeister SA, Roylance J and Ormerod CL..Fat loss. In: Penn J,ed. Brenthurst papers. Problems in eye lid and socket reconstruction. Witwatersrand University Press Johannesberg 1944:4-16.
44. Grabb WC. Basic techniques in plastic surgery. In: Grabb WC, and Smith JW, eds. Plastic surgery. A concise guide to clinical practice. Little, Brown and Company, Boston 1973;3-74.
45. Free skin grafts. In: Barsky AJ, Kahn S, and Simon BE,eds. Principles and practice of plastic surgery. McGraw-Hill Book Company 1964;34-62.
46. Scar revision. In: Georgiade GS, Riefkohl R, and Levin LS,eds. Georgiade plastic, maxillofacial and reconstructive surgery. Williams and Wilkins 1997;117.
47. Anatomy and physiology. In: Battle RJV,ed. Clinical surgery. Plastic surgery. Butterworths, London 1965;115.
48. Skin flaps and pedicles. In:Mclaughlin CR,ed. Plastic surgery. An introduction for nurses. Faber and Faber Limited London :49-57.
49. Primary repair. In:Mustarde JC,ed. Repair and reconstruction in the orbital region. A practice guide. Churchill Livingstone 1969;2-16.
50. Vistnes LM. Basic principles of cutaneous surgery. In:Epstein E, and Epstein E Jr,eds. Skin Surgery. W.B.Saunders Company 1987;44-55.
51. Stasko T. Advanced suturing techniques and layer closure. In: Wheeland RG,ed. Cutaneous surgery. W.B.Saunders Company 1994;304-17.
52. Borges AF. Dog ear repair. Plast Reconst Surg 1982;69(4):707-13.
53. Weisberg NK, Nehal KS, and Zide BM. Dog-ears: a review. Dermatol Surg 2000;26:363-370.
54. Zitelli JA. Tips for a better ellipse. J Am Acad Dermatol 1990;22:101-3.
55. Complex closure. In:Bennett RG,ed. Fundamentals of cutaneous surgery. The C.V. Mosby Company 1988;473-91.
56. Leshin B. Proper planning and execution of surgical excisions.In: Wheeland RG,ed. Cutaneous surgery. W.B.Saunders Company 1994;171-7.

57. Dunlavey E, and Leishin B. The simple excision. Dermatol Clinics 1998;16(1):49-64.
58. Ellipse. In: Stegman SJ, Tromovitch TA, and Glogau RG,eds. Basics of dermatologic surgery. Year Book Medical Publishers, Inc. Chicago, London 1982;60-8.
59. Mackay GJ, Carlson GW, and Bostwick J. Plastic and maxillofacial surgery. In: Sabiston DC,ed. Textbook of surgery seventh edition. WB Saunders company 1997;1298-33.
60. Wood RJ and Jurkiewicz. Plastic and reconstructive surgery. In: Schwartz SI, Shires GA, Spencer FC, Daly JM, Fischer JE, and Galloway AC, eds. Principles of surgery seventh editon. McGraw Hill 1999;2091-143.
61. Walker WF. Plastic surgery. In: Walker WF,ed. A colour atlas of minor surgery. Wolfe Medical Publications Ltd 1986;134-43.
62. Raveh Tilleman T, Tilleman M.M ,Krekels GAM and Neumann HAM. Skin waste and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, diamond, mosque and S-shape. Plast Reconst Surg 2004:113:857-861.
63. Moss RL, Henry MCW, Dimmitt RA, Rangel S, Geraghty NG, Skarsgard ED. The role of prospective randomized clinical trails in pediatric surgery:State of the art?. J Pediatr Surg 2001;36:1182-6.
64. Solomon MJ, McLeod RS. Should we be performing more randomized controlled trails evaluating surgical operations. Surgery 1995;118:495-67.
65. Moody BR, McCarthy EM, and Sengelmann RD. The apical angle: a mathematical analysis of the ellipse. Dermatol Surg 2001;27:61-3.
66. Raveh Tilleman T, Tilleman M.M, Smeets N, and Neumann HAM. Skin waste in elliptical excision biopsies . Accepted to the Scand J Plast Reconstr Surgery Hand Surg.

Table 1: Summarized data of 57 published ellipses: average vertex angles and length-to-width ratio.

#	Ref. No.	In vivo (photo)	Average angle (degree)	Length-to-width ratio
1	20		70	3.3
2	20		65	2.5
3	21	Yes	38.75	3.67
4	22		77.5	3.03
5	23	Yes	70	2.6
6	23	Yes	42.5	2.75
7	24		45	3.5
8	24		50	4.3
9	25		36.25	5.9
10	59		32.5	4.67
11	26	Yes	52.5	3.25
12	26	Yes	73.75	2
13	27		77.5	3.4
14	27	Yes	67.5	3
15	28		92.5	2.05
16	29	Yes	37.5	3.4
17	30		32.5	4.73
18	31		43.75	2.65
19	32	Yes	52.5	2.57
20	33		58.75	3.62
21	34		66.25	3
22	35		62.5	2.71
23	36		98.75	3.17
24	37		38.75	3.08
25	38		95	1.81
26	39		90	3.28
27	40		80	3.55
28	41		60	2.21
29	42	Yes	77.5	2.2

#	Ref. No.	In vivo (photo)	Average angle (degree)	Length-to-width ratio
30	43		57.5	3.29
31	44		60	2.88
32	44		50	2.67
33	44		63.75	2.56
34	44		67.5	2.3
35	45		47.5	2.75
36	46		110	1.85
37	47		65	2.75
38	48		75	2.69
39	49		37.5	6.17
40	50		67.5	3.27
41	51		52.5	3.8
42	52	Yes	70	2.8
43	53	Yes	42.5	3.89
44	54		57.5	3
45	55		36.25	5.67
46	55		60	3.73
47	56		86.25	2.05
48	56		61.25	3.25
49	57		62.5	2.875
50	58		50	3.21
51	60		47.5	2.8
52	60		50	3
53	60		52.5	3.24
54	61	yes	88.75	1.73
55	61	yes	75	1.71
56	61	yes	60	2.38
57	61	yes	90	1.67

Table 2: Summarized data of 83 clinical ellipses: average vertex angles and length-to-width ratio.

#	Average angle (degree)	Length-to-width ratio
1	48.1	6.33
2	50.4	4.5
3	42.5	4.4
4	45.0	4.17
5	58.6	3.5
6	65.1	3.5
7	54.1	3.5
8	47.2	3.43
9	46.4	3.33
10	58.5	3.29
11	58.4	3.25
12	46.4	3.22
13	51.1	3.17
14	53.5	3.17
15	47.9	3.17
16	51.3	3.17
17	45.6	3.14
18	55.2	3.13
19	58.4	3.09
20	58.5	3
21	68.5	2.91
22	53.5	2.91
23	58.4	2.89
24	57.7	2.88
25	60.8	2.8
26	60.8	2.73
27	63.1	2.69
28	61.7	2.64
29	58.4	2.56
30	65.0	2.56
31	60.0	2.55
32	55.9	2.53
33	72.0	2.50
34	63.3	2.50
35	60.0	2.5
36	61.7	2.5
37	60.0	2.5
38	62.5	2.5
39	65.9	2.5
40	60.8	2.5
41	63.4	2.45
42	61.8	2.44
43	63.3	2.42
44	66.9	2.38
45	60.1	2.33
46	63.3	2.30
47	72.2	2.3
48	59.3	2.3
49	83.0	2.29
50	63.4	2.23
51	69.5	2.20
52	65.0	2.18
53	72.9	2.1
54	75.2	2.06
55	91.8	2.05
56	71.1	2.03
57	85.7	2.00
58	76.9	1.96

#	Average angle (degree)	Length-to-width ratio
59	79.7	1.93
60	83.0	1.84
61	105.6	1.83
62	87.7	1.79
63	97.6	1.78
64	97.6	1.75
65	79.7	1.74
66	87.7	1.73
67	78.9	1.71
68	85.7	1.70
69	90.2	1.69
70	89.6	1.67
71	87.7	1.64
72	88.5	1.62
73	78.9	1.60
74	97.9	1.59
75	93.1	1.57
76	107.7	1.55
77	109.7	1.53
78	92.2	1.50
79	95.0	1.49
80	98.6	1.47
81	95.7	1.46
82	88.4	1.36
83	117.9	1.29

Table 3: Comparison of empirical vertex angles and theoretical calculations.

	Vertex angle for Length-to-width ratio of 3	Vertex angle for Length-to-width ratio of 4	Length-to-width ratio for vertex angle of 30°
Data (literature)	58°	48°	7.5
Data (our excisions)	59°	47°	7.5
Theory – fusiform ellipse	67°	53°	7.5

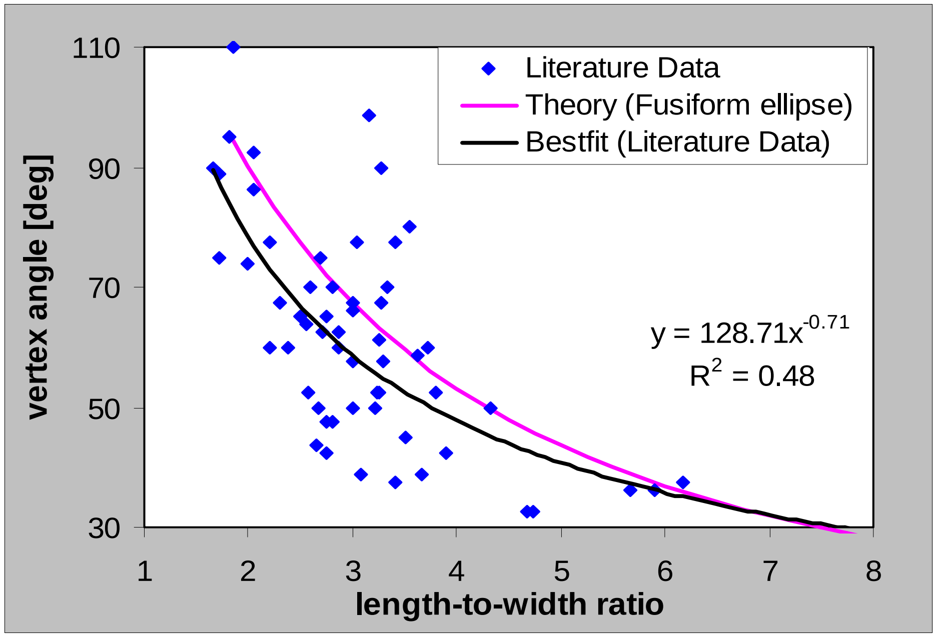

Figure 1: Vertex angle of the cited surgical ellipses as a function of the length-to-width ratio. The data are represented by the dots, the best-fit curve is the black solid line and the theoretical curve is the pink solid line.

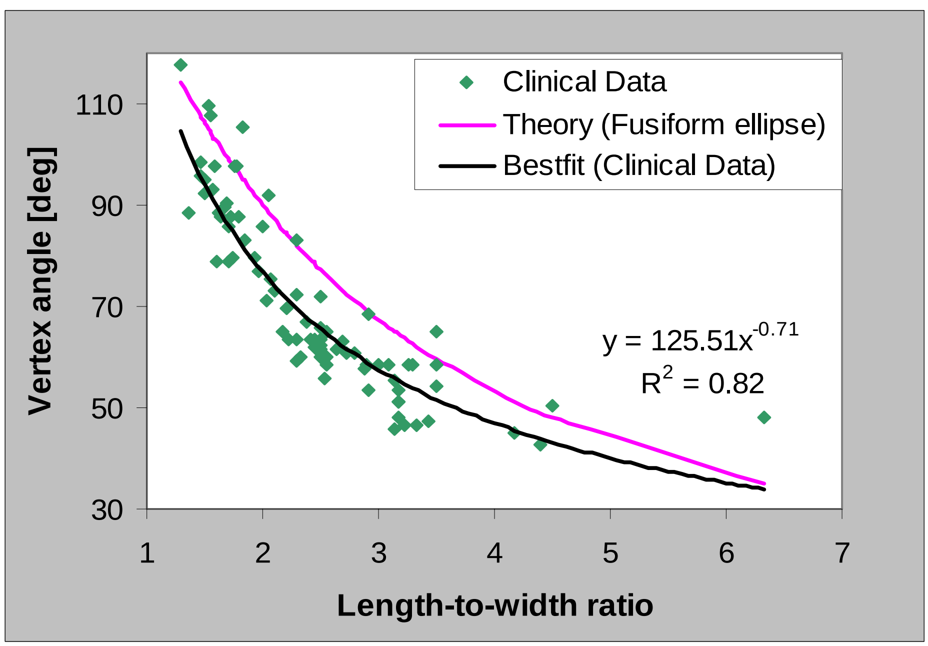

Figure 2: Vertex angle of our clinical ellipses as a function of the length-to-width ratio. The data are represented by the dots, the best-fit curve is the black solid line and the theoretical curve is the pink solid line.

Chapter 4

The analyses of skin waste during excision of benign skin lesions. Is the surgical ellipse cut an unnecessary cut?

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Abstract

Elliptical excision is the common cut in cutaneous surgery. In this work we investigate the skin waste of the surgical ellipse in biopsies of benign skin lesions. The skin waste is defined as the ratio of the difference between the excised elliptical area and the original lesion area, to the lesion area (plus margins for both).

Ninety consequential excisional biopsies performed at our outpatient clinic are analyzed. The results show that the surgical ellipse cut is a skin wasting procedure. The measured skin waste spans the range between 57% and 733%, with a mean of 181%. The largest skin waste was observed for small lesions, occurring in the head and neck regions. The ellipse cut is therefore an unnecessary surgical procedure especially for small, benign lesions. For these lesions a shave biopsy or a circular block excision is the best procedure. It wastes less skin and produces shorter scars. Consequently, we see no apparent justification for the elliptical cut paradigm for benign lesions.

Introduction

All humans have a number of benign skin lesions (1-3). Some of these are removed during the life span of a person for either cosmetic reasons or for preventive treatment (4-6). In order to extract tissue from a skin lesion, an excisional biopsy is frequently performed. The removed specimen undergoes further laboratory processing and microscopic analysis.

Skin biopsies are a common procedure in cutaneous surgery. Out of several possible surgical cuts, the surgical ellipse is the most common cutting pattern used for biopsies. The elliptical cut offers fast healing, good esthetic result, and sufficient specimen for histological examination (7). A properly designed elliptical excision has a length-to-width ratio of 3:1 and produces an angle of 30º at both apices of the wound (8). So designed an excision can be closed primarily thus avoiding the formation of excessive mounds of tissue at the wound vertices or dog-ears. Otherwise, the dog-ears will require additional mending by one out of ten or more methods of dog-ear correction (9,10).

The purpose of this study is to quantify the wasted skin in excisional biopsies of non cancerous skin lesions. Skin waste is hence defined as the ratio of the difference between the excised elliptical area and the original lesion area, to the lesion area.

Patients and Methods

Data of ninety consequential biopsies performed at our outpatient clinic for benign skin lesions were recorded. Only those lesions that were further histologically proved as completely excised were included. All the histological results were benign including: nevi, warts, fibro epithelial polyps, seborrheic keratoses, dermatofibromas, and pyogenic granuloma. Measured dimensions of the lesions and of the excised ellipses are summarized in Table I. Forty five patients had lesions located on the head and neck and forty five patients had lesions located on the body.

The area of the lesion is calculated by:

$$A_{lesion} = \pi/4 \; b \times d \tag{1}$$

where: b is the short diameter and d is the long diameter of the ellipse.

We chose the following ellipse formula to model the surgical ellipse area (11):

$$A_{ellipse} = \frac{S^2}{8}\left[\left(a^2+1\right)^2 \sin^{-1}\left(\frac{2a}{a^2+1}\right) - 2a\left(a^2-1\right)\right] \tag{2}$$

where: S is the width of the fusiform ellipse and a is the aspect ratio (length-to-width ratio). The skin waste is defined as the ratio of the difference of equations (1) and (2), and the lesion area plus margins (Eq.(1)):

$$waste = \frac{A_{ellipse} - A_{lesion}}{A_{lesion}} \tag{3}$$

Results

Summarized in Table I are the lesion and excision data, and the calculated skin waste. The lesion length varied between 2 mm and 32 mm and the lesion width varied between 2 mm and 29.5 mm. The excision length varied between 6.5 mm and 54.5 mm and the width varied between 3 mm and 33 mm. The mean length-to-width ratio of the excisions was 2.43:1. The area of the lesions varied between 3.14 mm^2 and 741 mm^2 and the area of the excised surgical ellipse varied between 13.54 mm^2 and 1283 mm^2. The skin waste was found in the range of 57% to 733% with a mean of 181%.

Figure 1 plots the skin waste (percent) versus the lesion area. Observe that the wasted skin decreases monotonously with the lesion area. Note that the skin waste is vastly larger for small lesions, 733% for 3.14 mm^2, than for large lesions, 57% for 616 mm^2. Thus small lesions cause large skin waste whereas large lesions cause small waste. Approximating a power regression curve the wasted area is typified by:

$$waste = 1.15 A_{lesion}^{-0.37}, \text{ with } R^2=0.69.$$

Figure 2 breaks up the data of Figure 1 into two groups: lesions from the head and neck, and lesions from the rest of the body. To emphasize the small lesions, the skin waste is plotted against the lesion area on a logarithmic scale. The largest amount of skin waste was found when small lesions in the head and neck were excised. The average skin waste of the head and neck lesions is 240%, compared with an average of 120% for body lesions. This twofold waste occurs due to the following facts: 1) the head and neck excisions have a larger length-to-width ratio than the body excisions (2.75 versus 2.09), and 2) the head and neck lesions are smaller than the body lesions, yet the excision margins for both areas are similar. For the above two reasons, paradoxically, larger skin waste is obtained for the small lesions.

Another data fit shows that the excision area is proportional to the excision length, as shown in Figure 3. What follows is that even a small addition to the excision length affects dramatically the skin waste. For instance, by increasing the average length from 20 mm to 30 mm (growth of 50%), the excision area grows from 70 mm^2 to 142 mm^2 (growth of 100%).

Discussion

The surgical ellipse is the most common pattern used in excision and closure of cutaneous lesions. This study quantifies the wasted skin in excising benign cutaneous lesions. It varies between 57% and 733% in excess of the lesion area. This enormous wasted tissue noticed in both small and large lesions is for the purpose of producing a linear scar and avoiding dog-ear formation. What was noticed is that the smaller the lesion, the larger is the skin waste. This might be due to the reason that many smaller lesions were located on the head and neck where attention is paid to the final scar and a considerable effort is made to conceal it, ending up with a longer length-to-width ratio and larger skin waste.

It is recommended to prefer a shave biopsy or a round excision of the lesion which ends with a circular defect. With the use of a circular incision, adequate safe margins are obtained and, at the same time, waste of sound skin is minimized. Such a circular defect can be easily closed by one of three alternatives. The first is leaving the tissue open to heal by second intention (11), the second is a direct closure of the defect without dog-ear excision (12,13), and the third is a purse-string closure which uses circumferential tissue advancement (14-16). These three techniques produce excellent results with no additional scarring or tissue wasting and often the final scar is smaller than the original lesion. From our experience with the figure-of-8 direct closure (13) (see chapter 9) any wound diameter that can be closed by an ellipse is suitable for this technique as well. Other options for closing a circular defect (17,18) include: primary closure and dog-ear correction, skin graft, M-plasty, A-to-T closure, O-to-Z closure (19), lazy S (20), H-advancement flap (21) and variety of local skin flaps (22,23). These solutions are less effective. They compromise either the scar length or the amount of healthy skin wasted.

The elliptical cut is therefore an unnecessary surgical procedure especially for small benign lesions. For these lesions a shave diagnostic biopsy or a round block cosmetic excision is the best procedure. It yields less skin waste and shorter scars. Though the surgical ellipse cut was found as the least advantageous skin excision pattern (24, see Chapter 2), it is routinely used. We see no apparent justification for the elliptical cut paradigm.

The conclusion is that for better tissue preservation and scar formation it is recommended that the surgical ellipse should be replaced by other skin cuts.

References

1. Pariser RJ. Benign neoplasms of the skin. Med Clin North Am. 1998;82:1285-307.
2. Luba MC, Bangs SA, Mohler AM, Stulberg DL. Common benign skin tumors. Am Fam Physician. 2003 15;67:729-38.
3. Rudolph P. Benign adnexal skin tumors. Pathologe. 2002 ;23(1):71-8.
4. Monteagudo C, Ferrandez A, Gonzalez-Devesa M, Llombart-Bosch A. Psammomatous malignant melanoma arising in an intradermal naevus. Histopathology. 2001;39:493-7.
5. Betti R, Menni S, Cerri A, Vergani R, Crosti C. Seborrheic keratosis with compound nevus, junctional nevus and basal cell carcinoma in the same lesion. Dermatology. 2001;203:265-7.
6. Jin ZH, Kumakiri M, Ishida H, Kinebuchi S. A case of combined nevus: compound nevus and spindle cell Spitz nevus. J Dermatol. 2000 ;27:233-7.
7. Dunlavey E, Leshin B. The simple excision. Dermatol Clin. 1998;16:49-64.
8. Zuber TJ, Dewitt DE. The fusiform excision. Am Fam Physician. 1994:1;49:371-80.
9. Weisberg NK, Nehal KS, Zide BM. Dog-ears: a review. Dermatol Surg. 2000;26:363-70.
10. Zitelli JA. Tips for wound closure. Pearls for minimizing dog-ears and applications of periosteal sutures. Dermatol Clin. 1989;7:123-8.
11. Lawrence CM, Comaish JS, Dahl MG. Excision of skin tumours without wound closure. Br J Dermatol. 1986 ;115:563-71.
12. Davis TS, Graham WP 3rd, Miller SH. The circular excision. Ann Plast Surg. 1980 ;4:21-4.
13. Raveh Tilleman T. Direct closure of rounded skin defects: A four-step technique with multiple subcutaneous and cutaneous “figure-of-8” sutures alleviating dog-ears. Accepted to the Plast Reconstr Surg.
14. Yuen JC. Versatility of the subcuticular purse-string suture in wound closure. Plast Reconstr Surg. 1996;98:1302-5.
15. Tremolada C, Blandini D, Beretta M, Mascetti M. The "round block" purse-string suture: a simple method to close skin defects with minimal scarring. Plast Reconstr Surg. 1997 ;100:126-31.
16. Weisberg NK, Greenbaum SS. Revisiting the purse-string closure: some new methods

and modifications. Dermatol Surg. 2003;29:672-6.

17. Romiti R, Randle HW. Revisiting the purse-string closure: some new methods and modifications. Dermatol Surg. 2003;29:672-6.
18. Hanke CW. Repair of surgical defects. Dermatol Clin. 1987;5:287-302.
19. Robbins TH. Double rotation skin closure: an alternative to elliptical closure. Aust N Z J Surg. 1978;48:650-2
20. Buckingham ED, Quinn FB, Calhoun KH. Optimal design of O-to-Z flaps for closure of facial skin defects.Arch Facial Plast Surg. 2003;5:92-5.
21. Rosenberg L A versatile procedure for the closure of small skin defects. Aesthetic Plast Surg. 1985;9:23-6.
22. Albom MJ. Closure of excisional wounds with "H" flaps.J Dermatol Surg. 1975;1(4):26-7.
23. Alvarado A. Reciprocal incisions for closure of circular skin defects. Plast Reconstr Surg. 1981;67:482-91.
24. Warren SE, Snell GF. Complex wound closure, excisional biopsy, and use of simple flaps. Prim Care. 1986;13:433-45.
25. Raveh Tilleman T ,Tilleman M.M ,Krekels GAM and Neumann HAM. Skin waste and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, diamond, mosque and S-shape. Plast Reconst Surg 2004;113:857-861.

Table 1 : Data of the lesions and excisions in millimeters, and the calculated skin waste.

	Location	Lesion length	Lesion width	Excision length	Excision width	Aspect $a=L/w$	Lesion area	Ellipse area	Skin waste	Surgical margin
1	Body	13	13	24	14	1.71	132.73	238.58	79.74%	0.50
2	Body	23	21.5	44	24	1.83	388.38	744.27	91.63%	1.25
3	Head	8	8	16	9	1.78	50.27	101.83	102.58%	0.50
4	Body	9	8.5	17.5	11	1.59	60.08	137.97	129.63%	1.25
5	Body	20.5	18	41.5	21.5	1.93	289.81	625.64	115.88%	1.75
6	Body	32	29.5	54.5	33	1.65	741.42	1282.80	73.02%	1.75
7	Body	15.5	15	29.5	16.5	1.79	182.61	343.98	88.37%	0.75
8	Body	15	15	24.5	16	1.53	176.71	282.43	59.82%	0.50
9	Body	13	10	19	13	1.46	102.10	179.19	75.50%	1.50
10	Body	21.5	21.5	51.5	22.5	2.29	363.05	801.23	120.69%	0.50
11	Body	18.5	18.5	32	19.5	1.64	268.80	445.43	65.71%	0.50
12	Head	5	5	14.5	7	2.07	19.63	70.72	260.19%	1.00
13	Body	7.5	7.5	14.5	8.5	1.71	44.18	87.56	98.20%	0.50
14	Body	7	7	16	8	2.00	38.48	89.46	132.45%	0.50
15	Body	28	28	46.5	29	1.60	615.75	965.48	56.80%	0.50
16	Body	12	9	32	11	2.91	84.82	240.12	183.09%	1.00
17	Body	5.5	5	20	6	3.33	21.60	81.42	276.98%	0.50
18	Head	5	3	19	3	6.33	11.78	38.19	224.16%	0.00
19	Head	4.5	3	11	5	2.20	10.60	38.14	259.71%	1.00
20	Head	10	8	23	9	2.56	62.83	142.14	126.22%	0.50
21	Body	7.5	9	25	10	2.50	53.01	171.88	224.22%	0.50
22	Head	5	4	19	6	3.17	15.71	77.49	393.35%	1.00
23	Head	8	6.5	22	7.5	2.93	40.84	112.52	175.50%	0.50
24	Body	11	8.5	29	9	3.22	73.43	177.31	141.45%	0.25
25	Head	7.5	5	19	6	3.17	29.45	77.49	163.12%	0.50
26	Head	9	7	24	7.5	3.20	49.48	122.31	147.19%	0.25
27	Head	6	5	15	6	2.50	23.56	61.88	162.62%	0.50
28	Body	15	12	29	14	2.07	141.37	282.89	100.11%	1.00
29	Body	11.5	9	25	10	2.50	81.29	171.88	111.45%	0.50

30	Head	6	8	17	8	2.13	37.70	94.56	150.84%	0.00
31	Head	9	5	19	8	2.38	35.34	104.84	196.64%	1.50
32	Head	4	4	18	5.5	3.27	12.57	67.22	434.89%	0.75
33	Head	3	3	13	4	3.25	7.07	35.31	399.60%	0.50
34	Head	7	5	15	6	2.50	27.49	61.88	125.10%	0.50
35	Body	6.5	7	20	9	2.22	35.74	124.73	249.03%	1.00
36	Head	3	3	17	4.5	3.78	7.07	51.71	631.51%	0.75
37	Body	16.5	9	28	11	2.55	116.63	211.54	81.37%	1.00
38	head	5.5	4.5	16	6	2.67	19.44	65.77	238.32%	0.75
39	head	3	2.5	11.5	4	2.88	5.89	31.40	433.00%	0.75
40	head	6.5	4	14	5.5	2.55	20.42	52.88	158.98%	0.75
41	head	5	5	15	7	2.14	19.63	72.96	271.58%	1.00
42	head	6.5	4	19	6	3.17	20.42	77.49	279.50%	1.00
43	head	2	2	11	3.5	3.14	3.14	26.18	733.31%	0.75
45	body	4.5	5	15	5.5	2.73	17.67	56.45	219.45%	0.25
46	head	3.5	3	10.5	4	2.63	8.25	28.80	249.19%	0.50
47	Head	3.5	3	10	4	2.50	8.25	27.50	233.49%	0.50
48	Head	2	2	6.5	3	2.17	3.14	13.54	330.93%	0.50
49	Body	9	9	17.5	9.5	1.84	63.62	117.11	84.09%	0.25
50	Body	7	6	15	7	2.14	32.99	72.96	121.18%	0.50
51	Body	4	4.5	10.5	5.5	1.91	14.14	40.54	186.74%	0.50
52	Head	11	9	20.5	10	2.05	77.75	142.97	83.87%	0.50
53	Body	7.5	7	15.5	8	1.94	41.23	86.92	110.79%	0.50
54	Head	5	5	16	7	2.29	19.63	77.45	294.46%	1.00
55	Body	10	10	22	12	1.83	78.54	186.07	136.91%	1.00
56	Head	8	6	23	7	3.29	37.70	109.30	189.92%	0.50
57	Head	2.5	3	10	4	2.50	5.89	27.50	366.88%	0.50
58	Head	5	5	15	6	2.50	19.63	61.88	215.14%	0.50
59	Head	4.5	4.5	11.5	5	2.30	15.90	39.75	149.91%	0.25
60	Head	4	3	12.5	4	3.13	9.42	34.01	260.82%	0.50
61	Head	3.5	3.5	14	4	3.50	9.62	37.94	294.30%	0.25
62	Head	2	2	9	3	3.00	3.14	18.39	485.50%	0.50
64	Body	12	10	24	11	2.18	94.25	183.19	94.37%	0.50

65	Head	4	4	13	4.5	2.89	12.57	39.92	217.67%	0.25
66	Head	4	4	11	4.5	2.44	12.57	34.08	171.20%	0.25
67	Body	15	14	31.5	15	2.10	164.93	328.85	99.39%	0.50
68	Head	18	12	42	14	3.00	169.65	400.58	136.13%	1.00
69	Body	22	14	46	18	2.56	241.90	568.55	135.03%	2.00
70	Body	17	16	42	18	2.33	213.63	522.06	144.38%	1.00
71	Body	9	9	17	10	1.70	63.62	120.83	89.93%	0.50
72	Body	15	15	28	17.5	1.60	176.71	350.92	98.58%	1.25
73	Head	9	6	18.5	7	2.64	42.41	88.76	109.28%	0.50
74	Head	11	9	24	9.5	2.53	77.75	156.66	101.48%	0.25
75	Head	14	4	25	6	4.17	43.98	101.14	129.96%	1.00
76	Body	13.5	14	30.5	15	2.03	148.44	319.28	115.09%	0.50
77	Body	9	9	16.5	10	1.65	63.62	117.70	85.01%	0.50
78	Body	12.5	9	23	10	2.30	88.36	158.98	79.93%	0.50
79	Body	21	13.5	43	16	2.69	222.66	471.13	111.59%	1.25
80	Body	20	16	39	19	2.05	251.33	516.71	105.59%	1.50
81	Body	12	12	26	15	1.73	113.10	276.56	144.54%	1.50
82	Body	11	10	24.5	11	2.23	86.39	186.71	116.12%	0.50
83	Head	9	8	22	9	2.44	56.55	136.32	141.06%	0.50
84	Head	8	8	18	9	2.00	50.27	113.22	125.25%	0.50
85	Body	18	17	35	19	1.84	240.33	468.46	94.92%	1.00
86	Head	8	7	16	9	1.78	43.98	101.83	131.52%	1.00
87	Head	11	7	21.5	9	2.39	60.48	133.41	120.61%	1.00
88	Head	9	11	23	13	1.77	77.75	211.54	172.06%	1.00
89	Body	12	10	30.5	11	2.77	94.25	229.38	143.38%	0.50
90	Body	10.5	8	16	10	1.60	65.97	114.59	73.69%	1.00
	Average					2.43			180.96%	
	STD					0.71			121.06%	
	Max	32.00	29.50	54.50	33.00	6.33	741.42	1282.80	733%	2.00
	Min	2.00	2.00	6.50	3.00	1.46	3.14	13.54	57%	0.00

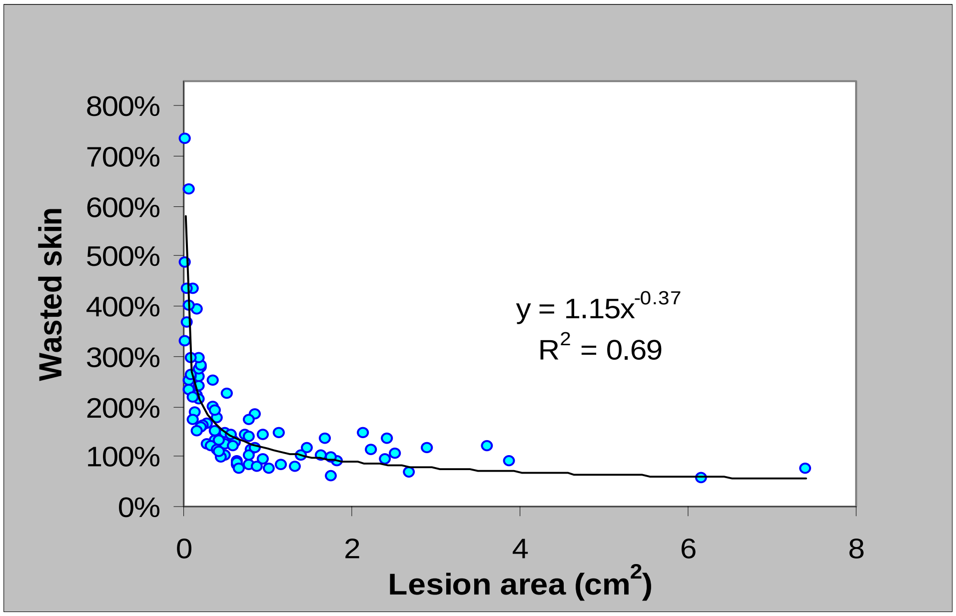

Figure 1: The skin waste (percent) versus the lesion area (cm^2). Observe that the wasted skin decreases monotonously with the lesion area. The solid line is the best–fit curve of the data.

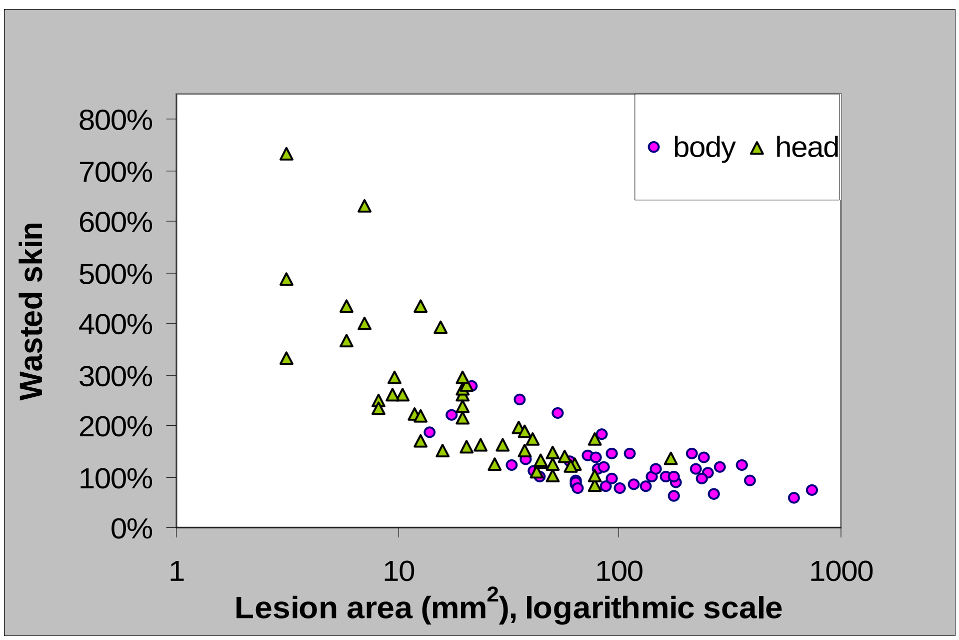

Figure 2: The skin waste (percent) versus the lesion area (mm^2) in a logarithmic scale. Lesions on the head and neck are triangular green and lesions on the body are round pink.

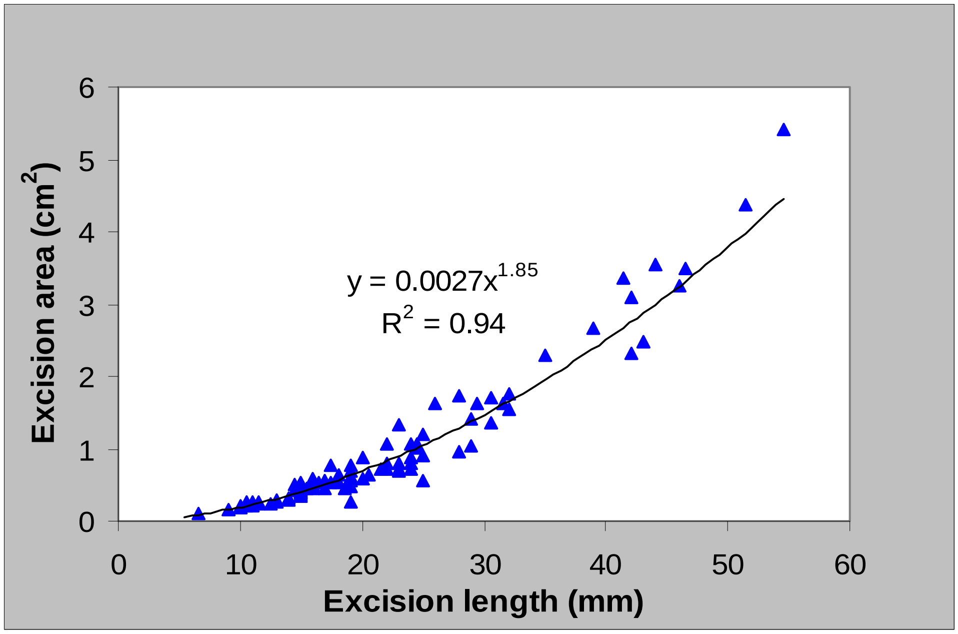

Figure 3: Excision area versus lesion length. The solid line is the best–fit curve of the data.

Chapter 5

Skin waste in elliptical excision biopsies of non melanoma skin cancers.

Publication:

Tamara Raveh Tilleman, Martino H.A. Neumann, Nicole W.J. Smeets, and Michael M. Tilleman. Accepted for publication in the Scand J Plast Reconstr Surgery Hand Surg 2004.

Presentation:

- Combined annual meeting of the American Society for Dermatologic Surgery (ASDS) and the American College of Mohs Micrographic Surgery (ACMMSCO). New Orleans October 2003
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Abstract.

This work quantifies the skin waste during elliptical excision biopsies of non melanoma skin cancers. The skin waste is defined as a ratio of the difference between the excised elliptical area and the original lesion area plus oncological margins, to the lesion area plus margins.

The analysis uses basic geometrical calculations of twenty six excisional biopsies of patients with non-melanoma malignant tumors. The measurements were performed at the last stage of Mohs' Micrographic Surgery (MMS). Huge tissue waste is noticed in both small and large excised lesions. The largest skin waste measured was 230% and the smallest was 34% with a mean of 130%.

Mohs' Micrographic Surgery is a skin sparing procedure, therefore the above mentioned huge tissue waste is unacceptable. The conclusion is that for better tissue preservation in closure of circular defects as a result of malignant tumor excision, other patterns should be adopted instead of surgical ellipses.

Introduction

Skin excisions are widely performed for skin lesions suspected as cancerous. Treatment of such cutaneous lesions should completely remove the tumor while preserving maximum of the healthy surrounding skin (1). Therefore, the surgery is a compromise between safe excision margins and obtaining a satisfactory esthetic result (2). The healthy skin removed in addition to the lesion is a byproduct of the skin cutting pattern and the necessary oncological therapeutic margin. In the literature there is no agreement as to the optimal width of surgical therapeutic margins. This amount of excised skin depends on the skin cancer type. Skin cancer such as basal cell carcinoma requires minimal margins whereas squamous cell carcinoma or malignant melanoma requires wider margins (3-5). Even the histological subtypes of a cancer play a role: for example, certain basal cell carcinomas behave more aggressively and require more aggressive treatment (6). Some authors recommend an optimum margin of 4 mm for all non melanoma skin cancer (7) while others found that these margins are suitable only for cutaneous lesions clinically diagnosed as basal cell (8). Others still believe that well demarcated lesions, such as a nodular basal cell carcinoma, may be excised with a 3 mm margin (2). Cited are also opinions which maintain that surgeons resect excessively wide surrounding skin carcinomas (9).

The therapeutic margins cannot be considered skin waste, because they are an oncological necessity. On the other hand, the healthy skin removed due to the cutting pattern enabling wound closure is considered pure skin waste. Many lesions are circular yet rarely the final excision is identical to the original pattern, resulting in the removal of healthy skin. The most common skin pattern used is a fusiform ellipse, which has become the standard pattern for skin lesion removal (10 – 12). To avoid dog-ear formation during elliptical excisions a vertex angle of 30˚ or less (13,14) and a length-to-width ratio between 3:1 to 4:1 are recommended (15 – 17).

The purpose of this study is to quantify the wasted skin in excisional biopsies of non melanoma skin cancers. Skin waste is hence defined as the ratio of the difference between the excised elliptical area and the original lesion area plus the therapeutic margins, to the lesion area.

Patients and Methods

Twenty–six patients, with non–melanoma malignant tumors (twenty four with basal cell carcinoma and two with squamous cell carcinoma tumors), on the forehead or the cheek, were consequentially chosen for this study from the outpatient department of dermatology at the Hospital Ziekenhuis Maastricht, Netherlands. All the patients underwent MMS and the measurements of the skin defect and the ellipse incision were performed at the last stage of the operation. Seventeen patients were males and the rest were females. Measured dimensions of the lesions and of the excised ellipses were recorded and are summarized in Table I. The excision length varied between 6 mm and 34 mm and the excision width varied between 6 mm and 27 mm. The mean length-to-width ratio of the excision was 3.13:1.

The area of the lesion is calculated by:

$$A = \pi/4 \; b \times d$$

where: b is the short diameter and d is the long diameter of the ellipse. We chose a fusiform ellipse to model the surgical ellipse. This is the area overlapped by two identical ellipses somewhat removed from one another. From basic geometrical principles the area of the fusiform ellipse is determined by (see Chapter 2):

$$A_{ellipse} = \frac{S^2}{8}\left[\left(a^2+1\right)^2 \sin^{-1}\left(\frac{2a}{a^2+1}\right) - 2a\left(a^2-1\right)\right]$$

where S is the width of the fusiform ellipse and a is the aspect ratio (length-to-width ratio). The skin waste is determined by the difference of the elliptical excision and the original lesion areas.

Results

Summarized in Table I are the lesion and excision data, and the calculated skin waste. The area of the excised lesions varied between 0.3 cm^2 and 7.2 cm^2. The area of the fusiform ellipse varied between 0.9 cm^2 and 15 cm^2. Figure 1 shows the areas of the excised lesion with oncological margins (orange bars) and the areas of the final excised ellipse (blue bars). The excision areas seem considerably larger than the lesion areas, implying excessive skin cut. Whereas the greatest lesion area (with its 3 millimeter margins) is 7 cm^2, its corresponding excision area measures 15 cm^2.

The lesion area is plotted against the excision area in Figure 2, showing a linear relation between the two. Discrete points denote the data and a bestfit curve is drawn as a line with a slope of 0.46 and a standard deviation of less than 10%. This means that the greater the lesion the greater is the excision area. The mean wasted skin area is 130%, with a standard deviation decreasing from 50% at 0.3 cm^2 to 30% at 4 cm^2. The largest skin waste was 230% and the smallest was 34%.

Shown in Figure 3 is the percentage of the skin waste versus the lesion area. Observe that the data scatter of the skin waste is vastly larger for small lesions, 130% for 0.3 cm^2, than for large lesions, 110% for 7.2 cm^2. Hence, the average fraction of the skin waste is nearly constant, independent of the lesion area.

The excision area is proportional to the square of the average length of the excision, as shown in Figure 4. What is implied is that any additional lengthening of the skin cut dramatically affects the amount of the skin waste. For instance, by increasing the average length from 30 mm to 40 mm (a growth of 33%), the excision area grows from 4.6 cm^2 to 8.2 cm^2 (a growth of 78%).

Discussion

Surgical extirpation of skin lesions and especially malignant tumors often results in circular or oval defects. The routine use of elliptical excision as a standard means of closure often creates needlessly long scars and skin waste. Many surgical alternatives exist for closing a circular defect (18 – 25). This study quantifies the wasted skin during cutaneous surgery of non-melanoma cancerous lesion. It varies between 34% and 210% beyond the lesion area. This skin waste seems extremely inappropriate when the operation performed is a Mohs' Micrographic surgery, an operation that heralds skin sparing as an aim.

The findings of this chapter are consistent with those of Chapter 4. The difference in the magnitudes of skin waste stems from the fact that in MMS discussed herewith the lesions are larger ab initio though they are located in the face. For the current lesion size of 0.3 cm^2 and 7.2 cm^2 we found a mean waste of 120%, similar to the finding of equivalent sizes in Chapter 4 (see figures 1 and 2 in Chapter 4).

The importance of this study lies in the sparing use of healthy tissue and shortening of scars. If sparingly used, the saved skin may serve as a future resource for reconstruction, a flap, for instance. This is true for both regular excisional biopsies, and for Mohs' Micrographic surgery (MMS). For the latter it is even more emphasized since there skin sparing is an objective in itself, therefore it is highly significant to optimize the cut. It would be imprudent for a surgeon performing MMS that spares millimeters of healthy margins throughout its stages, to willingly sacrifice lots of healthy skin in the reconstruction stage. The conclusion is that for better tissue preservation in closure of circular and oval defects patterns other than a surgical ellipse should be adopted.

References

1. Hudson-Peacock MJ, Matthews JN, Lawrence CM. Relation between size of skin excision, wound, and specimen. J Am Acad Dermatol. 1995 ;32:1010-5.
2. Lalloo MT, Sood S. Head and neck basal cell carcinoma: treatment using a 2-mm clinical excision margin. Clin Otolaryngol. 2000;25:370-3.
3. Epstein E. How accurate is the visual assesment of basal call carcinoma margins?. Br J Dermatol; 1973:89:37-43.
4. Brodland DG, Zitelli JA. Surgical margins for excision of primary cutaneous squamous cell carcinoma. J Am Acad Dermatol. 1992;27:241-8.
5. Haigh PI, DiFronzo LA, McCready DR.Optimal excision margins for primary cutaneous melanoma: a systematic review and meta-analysis. Can J Surg. 2003;46:419-26.
6. Orengo IF, Salasche SJ, Fewkes J, Khan J, Thornby J, Rubin F. Correlation of histologic subtypes of primary basal cell carcinoma and number of Mohs stages required to achieve a tumor-free plane. J Am Acad Dermatol. 1997;37:395-7.
7. Thomas DJ, King AR, Peat BG. Excision margins for nonmelanotic skin cancer. Plast Reconstr Surg. 2003;112:57-63.
8. Wolf DJ, Zitelli JA. Surgical margins for basal cell carcinoma. Arch Dermatol 1987;123:340-4.
9. Bisson MA, Dunkin CS, Suvarna SK, Griffiths RW. Do plastic surgeons resect basal cell carcinomas too widely? A prospective study comparing surgical and histological margins. Br J Plast Surg. 2002;55:293-7.
10. Grabb WC. Basic techniques in plastic surgery. In: Grabb WC and Smith JW, eds. Plastic surgery third edition. Little, Brown and Company, Boston;1979:3-8.
11. Chapter 8 ellipse. In: Stegman SJ, Tromovitch TA, and Glogau, eds. Basics of dermatologic surgery. Year book medical publishers Inc;1982:60-72.
12. Vistnes LM. Basic principales of cutaneous surgery. In: Epstein E and Epstein E Jr, eds. Skin surgery sixth edition. W.B.Saunders company;1987:44-55.
13. Dunlavey E and Leshin B. The simple excision. Dermatol Clinics. 1998;16:49-64.
14. Complex closures. In: Bennett RG, ed. Fundamentals of cutaneous surgery. C.V. Mosby Company;1988:473-491

15. Leshin B. Proper planning and execution of surgical excisions. In: : Wheeland RG,ed. Cutaneous surgery. W.B.Saunders company;1994:171-177.
16. Borges AF. Dog ear repair. Plast Reconst Surgery;1982:69:707-13.
17. Wound closure. In: Rohrich RJ and Robinson, eds. Wound healing. Selected redings in plastic surgery. University of Texax southwestern medical center and Bayelor University medical center;1999:9:18-20.
18. Healing by second intention. In: Fewkes JL, Cheney ML, and Pollack SV,eds. Illustrated atlas of cutaneous surgery. 1992;13.1-13.13.
19. Iriondo M. Healing by second intention. In: Wheeland RG,ed. Cutaneous surgery. W.B.Saunders company;1994: 892-900.
20. Drake LA, Dienehart SM, Goltz RW et al. Guidelines of care for Mohs micrographic surgery. J AM Acad Dermatol 1995;33:271-8.
21. Greenbaum SS, and Radonich MA. The purse-string suture. Dermatol Surg 1996;22:1054-6.
22. Teitelbaum S. The purse-string suture. Plast Reconst Surger 1998;101:1748-9.
23. Hudson-Peacock M.J., and Lawrence C.M. Comparison of wound closure by means of dog ear repair and elliptical excision. J Am Academ Dermato 1995;32:627-30.
24. Kirsner RS, Falanga V, and Eaglstein WH. The biology of skin grafts. Arch Dermatol. 1993;129:481-483.
25. Advancement flaps. In: Davidson TM, Webster RC, and Gordon BR, eds. The principles and dynamics of local skin flaps. American Academy of Otolaryngology. 1998; 26-37.

Table 1. Measurements of the lesion, the excised ellipse lengths and widths, and skin waste. Location 1 denotes the forehead and location 2 denotes the cheek.

#	Age	Location	Previous treatment	Gender	Surgeon	Lesion dimensions (mm)	Excision dimensions (mm)	Lesion area (cm^2)	Excision area (cm^2)	Skin waste (%)
1	66	1	Rec	F	1	6 x 6	21 x 6	0.28	0.85	202
2	69	2	Prim	M	2	15 x 9	25 x 9	1.06	1.54	45
3	71	1	Rec	F	2	13 x 12	33 x 13	1.23	2.95	141
4	72	2	Rec	F	2	13 x 12	35 x 12	1.23	2.86	134
5	82	1	Rec	F	1	20 x 8	42 x 8	1.26	2.26	80
6	82	1	Rec	M	2	14 x 12	30 x 13	1.32	2.70	104
7	60	1	Rec	F	1	16 x 11	45 x 11	1.38	3.34	142
8	63	1	Rec	M	2	16 x 12	39 x 16	1.51	4.30	185
9	85	1	Prim	M	1	16 x 12	39 x 12	1.51	3.18	111
10	73	1	Rec	F	2	15 x 15	34 x 15	1.77	3.53	100
11	86	1	Prim	M	1	17 x 15	45 x 15	2.00	4.60	130
12	86	2	Prim	M	2	20 x 13	28 x 14	2.04	2.74	34
13	60	1	Rec	M	1	18 x 15	52 x 15	2.12	5.29	149
14	60	2	Rec	F	2	19 x 16	41 x 16	2.39	4.50	89
15	70	2	Rec	F	1	20 x 16	73 x 16	2.51	7.86	213
16	83	1	Prim	M	2	18 x 20	62 x 20	2.83	8.44	198
17	83	1	Prim	M	1	22 x 19	70 x 19	3.28	9.00	174
18	71	1	Prim	M	2	21 x 20	50 x 20	3.30	6.88	108
19	86	2	Rec	F	2	23 x 21	47 x 22	3.79	7.19	89
20	79	1	Rec	M	2	24 x 20	62 x 20	3.77	8.44	124
21	77	1	Prim	M	2	26 x 16	73 x 16	3.27	7.86	141
22	60	1	Rec	M	1	25 x 20	60 x 20	3.93	8.18	108
23	86	2	Prim	M	2	34 x 27	84 x 27	7.21	15.43	114
24	58	1	Prim	M	1	14 x 10	45 x 12	1.10	3.65	232
25	58	2	Prim	M	1	20 x 19	56 x 20	2.98	7.65	156
26	58	2	Prim	M	1	15 x 15	40 x 15	1.77	4.11	133

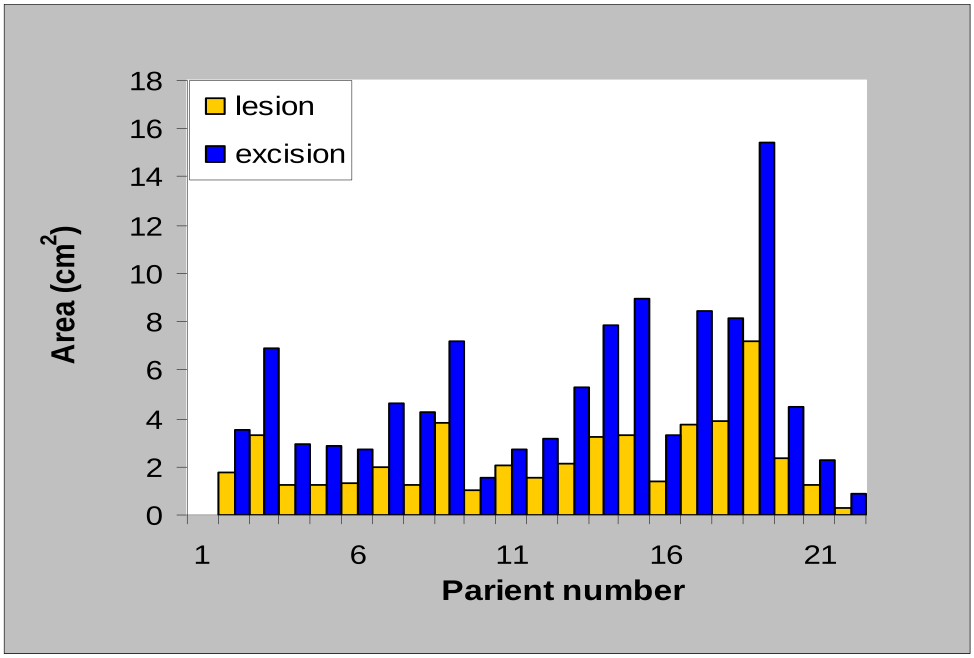

Figure 1: Areas of lesions (orange bars) and excisions made in a form of an fusiform ellipse (blue bars).

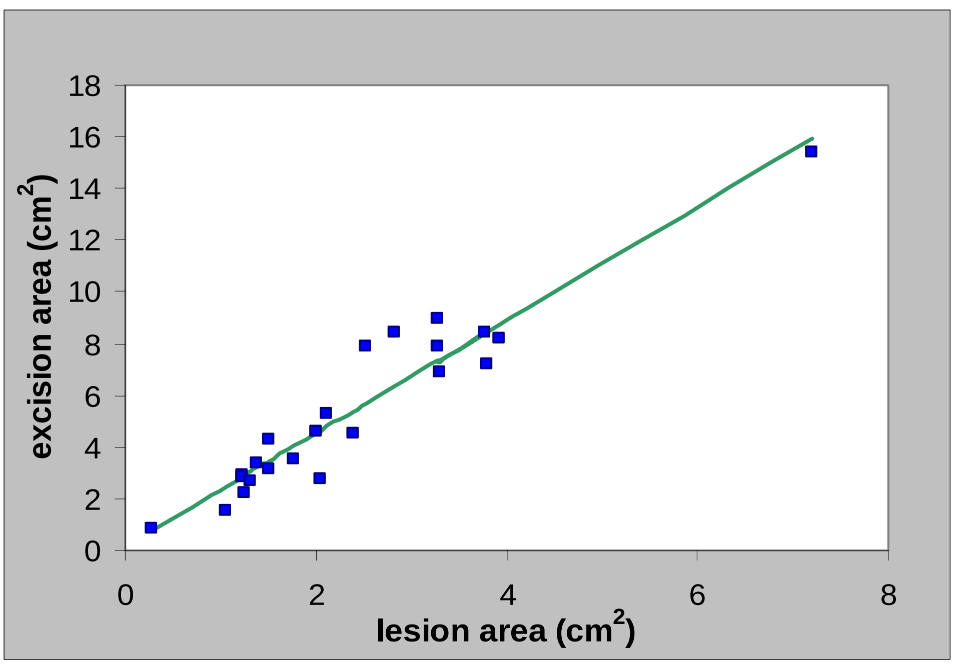

Figure 2: Excision area versus lesion area. The data are the discrete points and the solid line is a best--fit curve with a slope of 0.461.

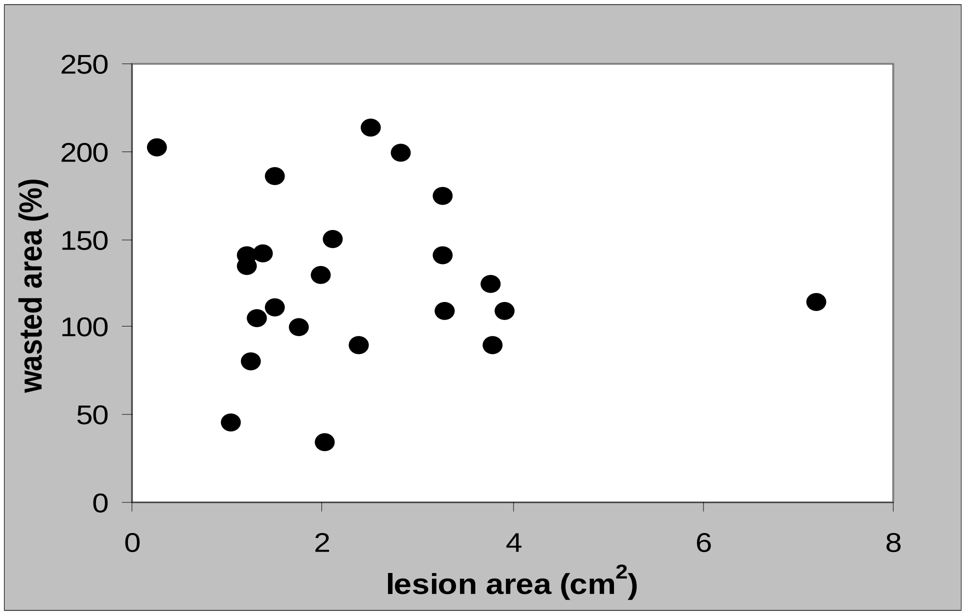

Figure 3: Percentage of wasted skin during excision. The average waste recedes slowly with the lesion area from 140% to 120%. On the other hand the point scattering decreases appreciably with the lesion area.

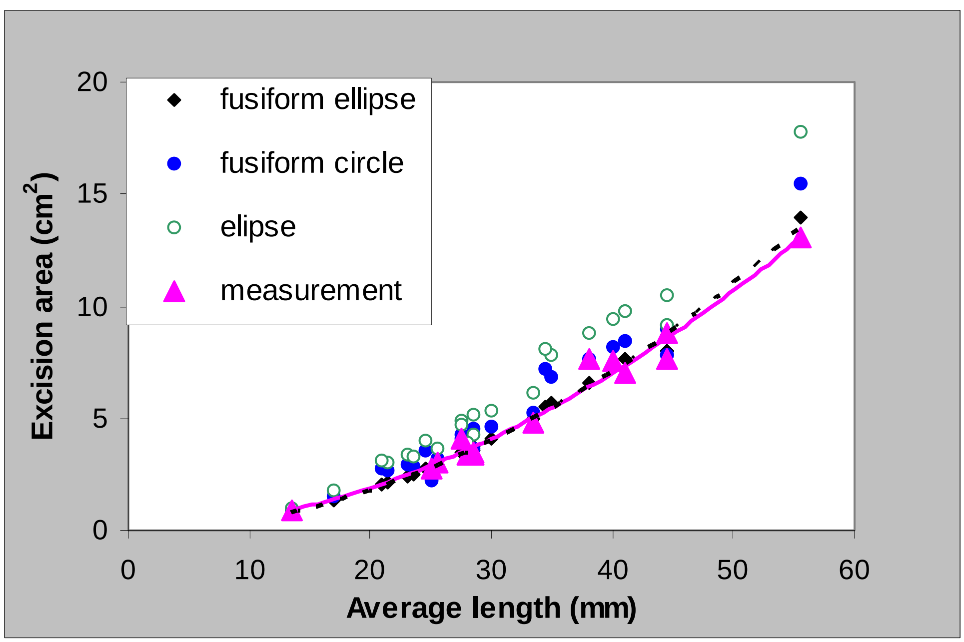

Figure 4: The excision area versus the average excision length. The solid line is the best–fit curve of the data and the broken line is the best–fit curve of the calculated fusiform ellipse.

Chapter 6

The elastic properties of cancerous skin: Poisson's ratio and Young's modulus.

Publication:

Raveh Tilleman T, MD , Tilleman MM, Neumann HAM. The elastic properties of cancerous skin: Poisson's ratio and Young's modulus. Submitted to and under second revision to:IMAJ 2004.

Abstract

Physical properties of cancerous skin tissue have rarely been measured in either fresh or frozen skin specimens. Of interest are the elastic properties associated with the skin ability to deform, i.e. to stretch and compress. Two constants, the Young's modulus and Poisson's ratio, represent the basic elastic behavior pattern of any elastic material, skin being one. The former relates the applied stress on a specimen to its deformation via the Hooke's law, while the latter is the ratio between the axial and lateral strains.

Our objective is to investigate the elastic properties of cancerous skin tissue. For this purpose frozen sections of twenty three consecutive cancerous tissue specimens prepared during Mohs micrographic surgery (MMS) were analyzed. We calculated from the data the change in the radial length defined as the radial strain and the change in the tissue thickness defined as axial strain.

Based on the above two strains we determined a Poisson's ratio of 0.43 ± 0.12 and an average Young's modulus of 52 KPa. Defining the elastic properties of cancerous skin may become the first step in turning elasticity into a clinical tool. Correlating these constants with the histopathological features of a cancerous tissue can contribute an additional noninvasive, in vivo and in vitro diagnostic tool. The elastic properties found in this work were used for calculations of the saucer incisions in MMS discussed in Chapter 7.

Introduction

Many physiological processes significantly change tissue properties. Pathological changes are generally correlated with changes in tissue elasticity. Cancerous tissue, such as carcinoma of the breast, appears as extremely hard nodules (11). This is the rational for palpation as a diagnostic tool in finding tumors of the prostate and breast (22,3). The palpation is a subjective test while in medicine the aim is to convert a physiological process into an objective test. Measuring the elasticity of cancerous tissues can yield an objective tool to be used in diagnostic models.

The properties of skin tissue in biomechanical research are commonly cited in the literature as applying to a material that is purely elastic, homogeneous and isotropic (44). It should be emphasized that real skin is unisotropic, heterogeneous and elastically nonlinear or viscoelastic, in either healthy or cancerous tissues. Therefore, a direct measurement of the cancerous skin properties is necessary.

Skin complex mechanical properties include the elastic properties of solid materials and the viscous properties of fluids (5). The elastic characteristics of the skin relate to the immediate changes that occur when force is applied to the skin. They govern the skin ability to deform, i.e. to stretch, contract and compress. These characteristics are defined by two physical constants: the Young's modulus, which relates the proportionality of the longitudinal deformation to the applied force (Hooke's law), and Poisson's ratio, which relates the dimensional deformations to one another (6). The viscous characteristics of the skin relate to the delayed changes occurring after time: the decreased stress obtained over time when a constant strain is applied (stress relaxation effect) and the increased length obtained over time when a constant strain is applied (creeping effect) (7). Surgeons are familiar with these effects, counting on stress-relaxation to release tension scar with time. They use the creeping effect to absorb some irregular scar features and dog-ears and to cause tissue elongation after inflating expanders.

Our interest is to explore the skin ability to deform. To gain understanding of the elastic behavior of the skin we set to measure the Young's modulus and Poisson's ratio. A common approach is to controllably compress a sample and measure the resulting deformation. One of the immediate implementations is to perform these measurements on a tissue before and after compression in a cryostat. This is a common process for immediate histology evaluation, available from surgeries that produce frozen sections.

Defining the elastic properties of normal and cancerous skin may become the first step in turning elasticity into a clinical tool. In the present work we measured the Young's modulus and Poisson's ratio of cancerous skin specimens, the first such measurement to the best of our knowledge.

Material and methods

In the analysis we used twenty three consecutive specimens excised from patients at our outpatient clinic. The specimen dimensions: length and thickness, in millimeters, were measured before and after compression and freezing using a caliper with an accuracy of 50 μm (0.05 mm). The cryostat chamber was set to -27°C (see Table 1), and a weight of 478 gram was used to compress the specimen (Figure 1). The compression in the cryostat is the first stage in producing frozen sections from the specimen. Inspection of the processed specimens under the microscope provides the histological diagnosis.

From the data we measured the change in the radial length and thickness of the tissue, and determined the resulting radial and axial strains. Based on the compressing weight and tissue dimensions we determined the stresses acting on the sample. From these, in turn, we determined the Young's modulus (the proportion coefficient between the strain and stress) and Poisson's ratio (the ratio between the radial strain and the axial strain). For this study we used only frozen sections that were further histologically proven as basal cell carcinoma.

Ice granules do not interfere with the measurement of the specimens because of two main reasons: 1) the time duration for the freezing of water having the size of our smallest sample is a few minutes, longer than the duration of the compression in the cryostat, 2) frozen water, or ice, would dramatically decrease the deformability of the tissue. Considering that ice Young's modulus is about 8 GPa, under the weight of 478 gram the deformation of the typical 10×2 mm is less than the dimension of an atom! Therefore, what was measured was the deformation of the cancerous tissue, with minimum freezing effect.

Our statistical evaluation assumes the present sample as normal, calculating accordingly the statistical averages, standard deviations and p-values.

Results

Twenty three consecutive cancerous tissue specimens prepared during frozen sections were analyzed. The twenty three analyzed tissue segments showed, after compression in the cryostat, an axial elongation varying from 12.66% to 44.33 %, with a mean of 17.7% (Table 1) and a standard deviation (STD) of 0.06. These tissues varied in width (radial thinning) from 7.33% to 30.86%, with a mean of 30.55% and STD of 0.09. The Poisson's ratio determined by the mean dimensions, with a measurement error of about 1%, resulted in 0.43 ± 0.12. With the positive stress being the ratio of the weight of 478 gram and the specimen area, we found a Young's modulus of 52 ± 45 KPa. Note that the Poisson's ratio calculated is not a regular average of the measured lengths. The reason is that commonly accepted elastic properties and the Hooke's law pertain to small deformations of the specimen. Because the present specimens underwent large deformations, one must use the known formulae carefully. Thus, one uses the mean lengths rather than the initial lengths as the normalizing dimensions.

The p-values were calculated based on the assumption of normal distribution. They are 15% the Poisson's ratio and 17% for the Young's modulus. These large values are consistent with the large variation of elastic properties of the skin cited in the literature (44,8,9).

Discussion

Normal skin and pathological skin possess different characteristics. For instance, cancerous tissue can appear as extremely hard nodules (11). The abnormal skin can be either cancerous or infected or a scarred tissue (88,10,11). Defining the elastic properties of cancerous skin and correlating these constants with the histopathological features of a cancerous tissue can contribute an additional noninvasive, in vivo and in vitro diagnostic (13). Poisson's ratio, a skin elastic characteristic, describes the behavior of materials under stress. For biological materials this constant ranges from 0.25 to 0.85 (14-22). Our measured Poisson's ratio for cancerous skin is 0.43, well within the cited range in the literature for biological tissues. In comparison, the Poisson's ratio for healthy human skin at room temperature has been cited in Ref. 8 as 0.5.

An example for clinical use of the Poisson's ratio was presented at the last annual meeting of the American College of Mohs Micrographic Surgery and Cutaneous Oncology (23). By using finite element analysis (ANSYS 5.6 Finite Element software package, with tetrahedron shaped elements represented by 1000 nodes), inputting the Poisson's ratio we determined, the minimum angle for an unobstructed view of a Mohs micrographic surgery cut was calculated. The angle was found 10º, smaller than the current norm in Mohs'. This approach is an example where elastic properties of the cancerous skin have a clinical application (2424).

The further measured Young's modulus shows an average of 52 KPa, well within the known values for various skins (44,13,25-28). Its deviation of 45 KPa about the mean is also well understood due to the significant variations in skin elasticity as a function of age, location, actinic changes and racial features. This variation explains the large p-value we found, 17% for Young's modulus and 15% for Poisson's ratio.

Our further objective is to investigate the correlation between the skin elastic properties and the histological findings of healthy skin and cancerous skin morphology. Such a clinical research is presently held in our departments aiming to specify the skin elastic properties according to the cancer features. Future practical uses of the a priori knowledge of the elastic characteristics of cancerous tissues is, for instance, finding the exact border between healthy and malignant tissue by a noninvasive measurement on the skin surface. Thus cancer screening, diagnosis and treatment modalities can benefit from a well defined, compiled and stored data body of these characteristics.

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References

1. Anderson RC, Curtin HR. Ultrasonic holography. A promising medical imaging tool. Radiology. 1973;109:417-21
2. Owen AW, Forrest AP, Anderson TJ, Samuel E, Young GB, Scott AM Breast screening and surgical problems. Br J Surg. 1977;64:725-8
3. Hedlund PO, Das D, Lowhagen T, Esposti P. Rectal palpation and transrectal fine needle aspiration of the prostate in the monitoring of prostate cancer: a study of 59 patients during treatment with estramustine phosphate or estrogens. Prostate. 1989;15:327-33
4. Larrabee, W.F.Jr. A finite element model of skin deformation: I Biomechanics of skin and soft tissue: A review. Laryngoscope. 1986;96(4):399-405.
5. Gilbson T, Kenedi RM. Biomechanical properties of skin. Surg North Am 1967;47:279-294.
6. Lee C, Vincent JF, and Hillerton JE. Poisson's ratio in skin. Biomed Matwe Eng. 199;1(1):19-23.
7. Wexler DB, Gilbertson LG, Goel VK, Bardach J. Biomechanics of the rotation-advancement skin flap: experimental and theoretical studies. In: Bardach J, ed. Local flaps and free skin grafts. Mosby year book, 1992. 53-68.
8. Larrabee,W.F.Jr., and Sutton, D. A finite element model of skin deformation: II An experimental model of skin deformation. Laryngoscope. 1986;96(4):406-12.
9. Kennedy RM, Gibson T, Daly CH. Bioengineering studies of the human skin in: Proc. symposium on biomechanics and related bioengineering topics. Kennedy RM, ed. Pergamon Press, Oxford, 1965; 147-58.
10. Miyauchi T, Maruoka M, Nagayama T. Malignant melanoma of the penis associated with von Recklinghausen's neurofibromatosis: report a case. Hinyokika Kiyo. 1988;34(4):710-3.
11. Tiu CM, Chiou HJ, Chou YH, Hsu CC, Lin KJ, Chen CM, Ko JS, Tseng LM, Lai CR, Lui WY. Sonographic features of breast abscesses with emphasis on "hypoechoic rim" sign.Zhonghua Yi Xue Za Zhi (Taipei). 2001;64(3):153-60.
12. Ulrich J, Voit C.Ultrasound in dermatology. Part II. Ultrasound of regional lymph node basins and subcutaneous tumours. Eur J Dermatol. 2001;11(1):73-9

13. Dobrin PB, Mrkvicka R.Estimating the elastic modulus of non-atherosclerotic elastic arteries. J Hypertens Suppl. 1992;10(6):S7-10.
14. Maaß H, Kühnapfel U. Noninvasive Measurement of Elastic Properties of Living Tissue, Proceedings of the European Medical and Biological Engineering Conference EMBEC,99, Medical & Biological Engineering & Computing. 1999;37(2):1460-1.
15. Mizunuma M, Yanai A, Tsutsumi S, et al. Can dog ear formation be decreased when an s shape resection is used instead of spindle skin resection? A three dimentional analysis of skin surgery techniques using finite element method. Plast Reconstr Surg. 2000;106(4):845-8.
16. Lee C, Vincent JF, and Hillerton JE. Poisson's ratio in skin. Biomed Matwe Eng. 199;1(1):19-23.
17. Boissieux L, Kiss G, Magnenat Thalmann N, Kalra P. Simulation of skin aging and wrinkles with cosmetics insight. http://66.102.11.104/search?q=cache:_traSCNhG7MJ
18. Ophir J, Cespedes I, Ponnekanti H, Yazdi Y, and Li X. Elastography: A quantitative method for imaging the elasticity of biological tissues. Ultrasonic imaging 1991;13: 111-34.
19. Mente, P.L., Lewis, J.L., 1994. Elastic modulus of calcified cartilage is an order of magnitude less than that of subchondral bone. Journal of Orthopaedic Research 12, 637}647.
20. Manios A, Katsantonis J, Tosca A, Skulakis CH, and Tsifisis D. The finite element method as a research and teaching tool in the analysis of local skin flaps. Dermatol Surg. 1996;22:1029-1033.
21. Erkamp RQ, Wiggins P, Skovoroda AR, Emelianov SY, O'Dodonnell M. Measuring the elastic modulus of small tissue samples.Ultrason Imaging. 1998;20(1):17-28.
22. Pieper SD, Laub DR, and Rosen JM. A finite element facial model for simulating plastic surgery. Plast Reconstr Surg. 1995;96(5):1100-5.
23. Raveh Tilleman T, Tilleman M and Neumann MHA. Minimum beveling in Mohs surgery cut. In: The combined annual meeting of the ASDS and ACMMSCO. October 9-12 New Orleans 2003.
24. Pellettiere J. A. Materiam model for bone under impact loading. http://asb-biomech.org/onlineabs/NACOB98/280

25. Mossel WP. Summary E-modulus of skin. w.p.mossel@io.tudelft.nl. http://isb.ri.ccf.org/biomch-l/archives/biomch-l-1997-12/00080.html
26. Mackay DR, Saggers GC, Kotwal N, Manders EK. Stretching skin: undermining is more important than intraoperative expansion. Plast Reconstr Surg 1990;86:722-30.
27. Khatyr F.; Imberdis C.; Vescovo P.; Varchon D.; Lagarde J-M. Model of the viscoelastic behaviour of skin in vivo and study of anisotropy. Skin Research Tech 2004;10:96-103.
28. Kiwaki H, Miyaoka Y, Arase S. Analysis of the absorbance spectra of skin lesions as a helpful tool for detection of major pathophysiological changes. Skin Res Technol. 2004;10:130-5.

Table 1: Summary of the Measured Specimen Dimensions, Strain, Poisson's ratio and Young's Modulus.

Initial diameter (mm)	Initial height (mm)	Final diameter (mm)	Final height (mm)	Radial strain	Axial strain	Poisson's ratio	Axial stress-to-strain ratio	Young's modulus (KPa)
8.85	3.15	9.85	2.4	10.70%	27.03%	0.40	0.026	42.57
9.9	3.15	11.85	2.45	17.93%	25.00%	0.72	0.021	25.83
9.75	4.85	11.55	2.7	16.90%	56.95%	0.30	0.009	17.26
8.1	4.85	10.6	2.7	26.74%	56.95%	0.47	0.012	18.83
10.2	4.65	11.2	3.65	9.35%	24.10%	0.39	0.022	36.75
8.45	4.65	9.8	3.65	14.79%	24.10%	0.61	0.030	41.25
9.85	4.55	10.75	3.4	8.74%	28.93%	0.30	0.020	36.11
9.1	4.55	10.95	3.4	18.45%	28.93%	0.64	0.021	27.92
7.5	3.95	8.05	3.45	7.07%	13.51%	0.52	0.075	109.35
8.75	3.15	10.2	2.25	15.30%	33.33%	0.46	0.020	31.63
9.65	3.15	10.8	2.2	11.25%	35.51%	0.32	0.016	29.38
5.45	3.15	5.85	2.55	7.08%	21.05%	0.34	0.091	158.99
7.35	4.05	8.95	2.45	19.63%	49.23%	0.40	0.019	30.67
4.15	3.85	5.2	2.5	22.46%	42.52%	0.53	0.065	95.73
10.45	3.95	12.5	2.55	17.86%	43.08%	0.41	0.011	17.41
4.5	3.95	5.55	2.45	20.90%	46.88%	0.45	0.051	80.98
7.15	2.4	8.9	1.55	21.81%	43.04%	0.51	0.022	32.71
6.5	2.5	8	1.5	20.69%	50.00%	0.41	0.023	37.60
9.9	2.45	11.35	1.85	13.65%	27.91%	0.49	0.019	29.24
6.35	2.45	7.3	1.95	13.92%	22.73%	0.61	0.057	78.28
8.85	3.15	10.75	1.9	19.39%	49.50%	0.39	0.013	21.24
3.8	2.75	4.25	1.85	11.18%	39.13%	0.29	0.096	177.98
10.05	3.7	12.15	2.1	18.92%	55.17%	0.34	0.009	15.61
			Average	15.86%	36.72%	0.43		51.88
			Std. dev.	5.33%	12.83%	0.12		44.85


Figure 1

Chapter 7

Minimal beveling angle in Mohs' micrographic surgery cut

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- Combined annual meeting of the American Society for Dermatologic Surgery (ASDS) and the American College of Mohs Micrographic Surgery (ACMMSCO). New Orleans October 2003
- 2^{nd} Annual Research Meeting. General Health Services, Rabin Medical Center, Petach Tikva ,Israel, November 2003.

Abstract

Saucer incision with a taper angle of 45°is the common cut in Mohs' micrographic surgery (MMS). The beveling is necessary for microscopic viewing of the cutting strata, however, its minimal angle has not been studied thus far. In this work we examine the 45° aspect of the saucer incision and answer the question what is the minimal beveling angle that permits viewing all the layers after the cryostat compression. The calculation method used is a finite elements analysis (ANSYS). Microscopic views of Mohs specimens are inspected to backup the analysis. It was found that 10° is the critical cone angle that permits complete layer viewing without obstruction. The conclusion, therefore, is that a minimal beveling of 10° instead of 45° can be carried out during MMS. It is more skin sparing, reducing the risk of invading the cancer and producing a better scar, while still providing adequate microscopic information.

Introduction

In the teaching of cutaneous surgery a perpendicular 90° cut is the norm (1,2). However, the skin cut in Mohs' micrographic surgery (MMS) differs from that in any other skin surgery. It aims to produce horizontal sections for histopathological viewing. Dr. Frederic Mohs recommended that tissue removed by the first excision should possess a saucer shape (3,4), i.e. a 45° beveled cut combined with a circular marginal incision. The beveled cut is needed to produce a good microscopic strata projection (5) by eliminating any tissue bulging during condensation in the cryostat (6).

This behavior is illustrated in Figure.1, where all the cone layers can be viewed before and after the compression. In contrast, the compression of a cylinder (an object with no taper) creates a barrel shape with a protruding middle section, therefore, masking layers from a microscopic view. The projection of the cone layers diminishes as the cone angle decreases. So far the minimal beveling of the Mohs specimen edge has not been shown or calculated, thus the taper angle of 45° in MMS remained the norm (7,8). In this work we examined the tapered aspect of the saucer incision and answered the question of what is the minimal beveling angle that permits viewing all the layers after the cryostat compression.

Materials and Methods

The method uses a three-dimensional finite element analysis and microscopic views of Mohs specimens. The finite element method (ANSYS 5.6 Finite Element software package, with tetrahedron shaped elements represented by 1000 nodes) is a basic engineering tool used for structure analysis, also used lately for modeling of body tissues (9-19). This software has the capacity to compute and display anatomic predictions of surgical manipulations (20). The finite analysis can model geometrically complex bioforms, such as human tissues, by discretizing the anatomy into many smaller components termed "elements", the fundamental unit of the finite elements model. A thoughtfully constructed finite element model of the skin can simulate the stretch and elasticity of a tissue (21). Current models of wound closure and skin flap movement are based upon geometrical or paper models (see the figures in Chapter 1). These models are not realistic because they ignore the elastic properties of skin and its subcutaneous attachments (9). The skin deformation based upon the finite elements model is a more effective and realistic model to describe skin movements.

In the calculation we used a Poisson ratio of 0.43, described in the previous chapter. Recall that we measured this Poisson's ratio in a cancerous tissue, rendering it valid for all the specimens used in this chapter. This value is within the cited range in the literature (4-17,22). The finite elements served to assess quantitatively the minimal angle cut that permits a complete microscopic layer projection.

Finally, specimens with various cut angles were photographed during MMS. The microscopic views are used to backup the above theoretical calculations by showing their layer projections.

Results

Using the finite elements method we analyzed a number of cones with a taper ranging from 0° to 45°. This simulates specimen compression in a cryostat during the preparation of frozen sections. Specifically, a dynamic analysis consisting of the original specimen sagging due to applied vertical force is conducted. Figure 2 presents a model having a taper of 45°. In the figure shown is the specimen before (left hand side) and after (right hand side) the compression. Observe that a complete layer is unobstructedly viewed after the compression, as schematically shown at the top of Figure 2.

Figure 3 presents a calculated model having a taper of 10° before (left hand side) and after (right hand side) the compression. As before, a complete layer viewing is attained after the compression though with a smaller projection. In analyzing cones with a taper ranging from 0° to 45° it was found that 10° is the critical cone angle which permits complete layer viewing without obstruction after cryostat compression. A smaller angle obscures some layers and renders the viewing imperfect.

This finding was supported by numerous MMS operations. A microscopic view of Mohs specimens is demonstrated in Figure 4. What is shown is that both a specimen with beveling angles of both 45° (a), and of an acute angle cut of 10° (b) present good layer projections.

Discussion

Mohs' micrographic surgery is based on the concept of microscopically scanning layers taken from the entire undersurface of the excised specimen (23). As a rule, the greater the angle the better is the viewing of the layers after compression. On the other hand, the greater the angle, the greater is the tissue waste and greater is the chance that the cancerous tissue will be revealed at the bottom of the specimen, increasing the probability of an additional MMS stage. Also, a 45° angle produces an epidermis and dermis acute tissue step that upon closure results in a nonlinear scar and a dog-ear creation. A smaller angle reduces the probability of the above drawbacks.

The commonly used taper angle of 45°, the legacy of Dr Mohs, has never been tested before. By using the finite elements method we found that a taper of 10° is the minimal beveling that permits projection and viewing of all the skin layers after the cryostat compression. This finding was supported by MMS specimens. Note that the calculation became possible once elasticity data of frozen, cancerous skin have been found (see Chapter 6). The conclusion is that a beveling of less than 45° but no less than 10° is recommended. It is more skin sparing, reduces the probability of intercepting the cancerous tissue, and produces a better scar.

References

1. Walkwer NPJ, Lawrence CM, Dawber RPR Simple excision. In: Textbook of dermatology, eds: Champion RH, Burton JL, Burns DA, Breathnach SM. Blackwell Science Ltd. Oxford 1998;3603-5.
2. Hak DJ, Goulet JA. Operative planning and perioperative management. In:Chapman's orthopedic surgery, ed: Chapman MW. Lippincott Williams and Wilkins 2001;75-120.
3. Brodland DG, Amonette R, Hanke CW and Robins P. The history and evolution of Mohs micrographic surgery. Dermatol Surg 2000;26:303-7
4. Drake LA, Dinehart SM, Goltz RW, Graham GF, Hordinsky MK, Lewis CW, Pariser DM, Salasche SJ, Skouge JW, Chanco Turner ML, Webster SB, Whitaker DC, Bulter B and Lowery BJ. Guidelines of care for Mohs micrographic surgery. J Am Acad Dermatol 1995;33:271-8.
5. Steinman HK. Mohs surgical techniques. In: Gross KG, Steinman HK, and Rapini RP,eds. Mohs Surgery: fundamentals and techniques. Mosby, Inc;1999:49-66.
6. Mohs' micrographic surgery. Chapter 29. In:. Fewkes JL, Cheney ML, and Pollack SV,eds. Illustrated atlas of cutaneous surgery. JB Lippincott Company;1992:29.2-29.12
7. Walkwer NPJ, Lawrence CM, Dawber RPR.Dermatological surgery: micrographic (Mohs) surgery. In:Textbook of dermatology, eds: Champion RH, Burton JL, Burns DA, Breathnach SM. Blackwell Science Ltd. Oxford 1998;3593-3623.
8. Greenway HT, Leslie DF. Mohs micrographic surgery for skin cancer. Australas J Dermatol 1991;32:159-64.
9. Larrabee, W.F.Jr. A finite element model of skin deformation: I Biomechanics of skin and soft tissue: A review. Laryngoscope. 1986;96:399-405.
10. Larrabee,W.F.Jr., and Sutton, D. A finite element model of skin deformation: II An experimental model of skin deformation. Laryngoscope. 1986;96:406-12.
11. Larrabee,W.F.Jr., and Galt, J.A. A finite element model of skin deformation: III The finite element model of skin deformation. Laryngoscope. 1986;96:413-9.
12. Manios A, Katsantonis J, Tosca A, Skulakis CH, and Tsifisis D. The finite element method as a research and teaching tool in the analysis of local skin flaps. Dermatol Surg. 1996;22:1029-1033.
13. Mizunuma M, Yanai A, Tsutsumi S, et al. Can dog ear formation be decreased when an

s shape resection is used instead of spindle skin resection? A three dimentional analysis of skin surgery techniques using finite element method. Plast Reconstr Surg. 2000;106:845-8.

14. Remmler D. Can dog ear formation be decreased when an s shape resection is used instead of spindle skin resection? A three dimentional analysis of skin surgery techniques using finite element method. Discussion. Plast Reconstr Surg. 2000;106:849-851.
15. Erkamp RQ, Wiggins P, Skovoroda AR, Emelianov SY, O'Dodonnell M. Measuring the elastic modulus of small tissue samples.Ultrason Imaging. 1998;20:17-28.
16. Costa, K.D., Hunter, P.J., Wayne, J.S., Waldman, L.K., Guccione, J.M., and McCulloch, A.D. A three dimentional finite element method for large elastic deformations of ventricular myocardium: II – prolate sphenoidal coordinates. J Biomech Eng. 1996;118:464-72.
17. Keyak JH, Fourkas MG, Meagher JM, and Skinner HB. Validation of an automated method of three-dimentional finite element modelling of bone. J Biomed Eng. 1993;15:505-9.
18. McCulloch A, Waldman L, Rogers J, and Guccione J. Large scale finite element analysis of the beating heart. Crit Rev Biomed Eng. 1992;20:427-49.
19. Pieper SD, Laub DR, and Rosen JM. A finite element facial model for simulating plastic surgery. Plast Reconstr Surg. 1995;96:1100-5.
20. Manios A, Katsantonis J, Tosca A, Skulakis CH, Tsifisis D, Finite element method as a research and teaching tool in the analysis of local skin flaps. Dermatol Surg 1996;22:1029-33.
21. Kirby S, Wang B, To C, Lampe HB. Non linear three dimensional finite element model of skin biomechanics. J otolaryngol 1998;27:153-60.
22. H. Maaß, U. Kühnapfel. Noninvasive Measurement of Elastic Properties of Living Tissue, Proceedings of the European Medical and Biological Engineering Conference EMBEC,99, Medical & Biological Engineering & Computing. 1999;37:1460-1.
23. Mohs FE. Mohs Micrographic Surgery a historical perspective. Dermatol Clinics 1989;7:609-626.

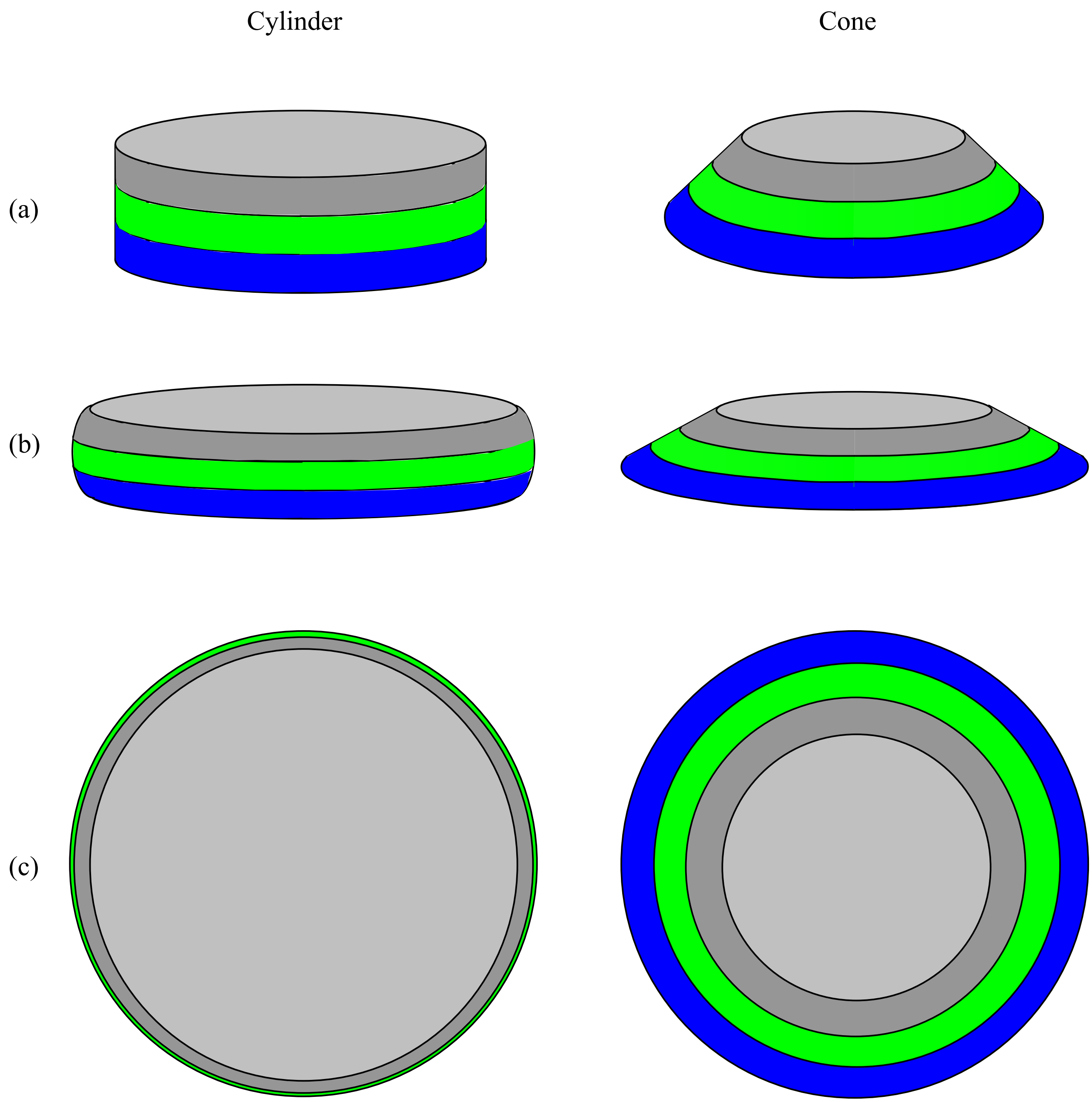


Figure 1: Comparison of tapered and cylindrical shapes before (a) and after compression (b and c). The view shown in (c) simulates the frozen cut sections analyzed under microscope during Mohs' micrographic surgery.

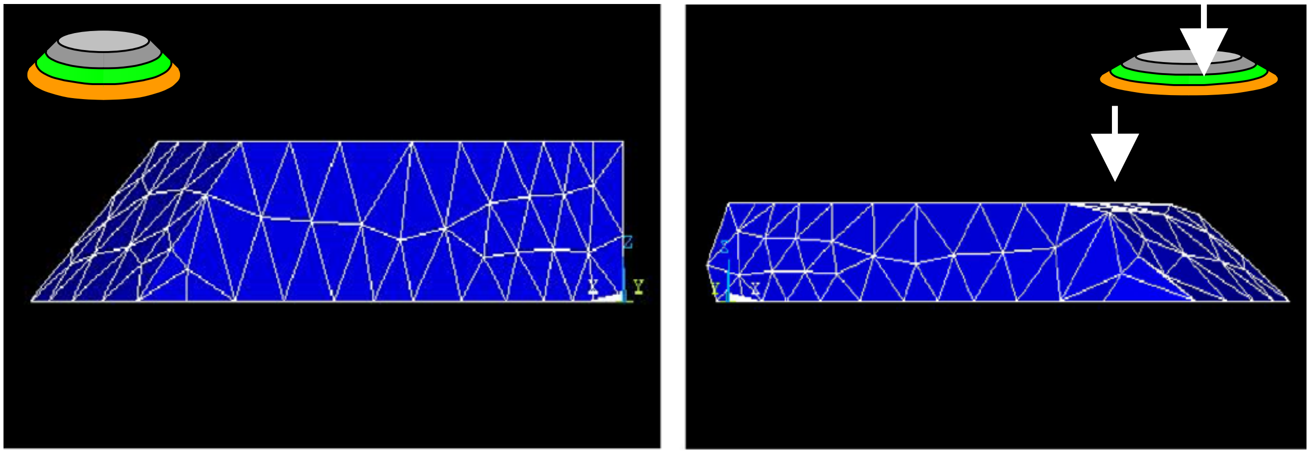


Figure 2: Finite Elements simulation of specimen compression: a calculated model having a taper of 45° before (left hand side) and after the compression (right hand side). Observe a complete layer viewing after the compression as presented both by the finite element model and by the small geometrical illustration (on top).

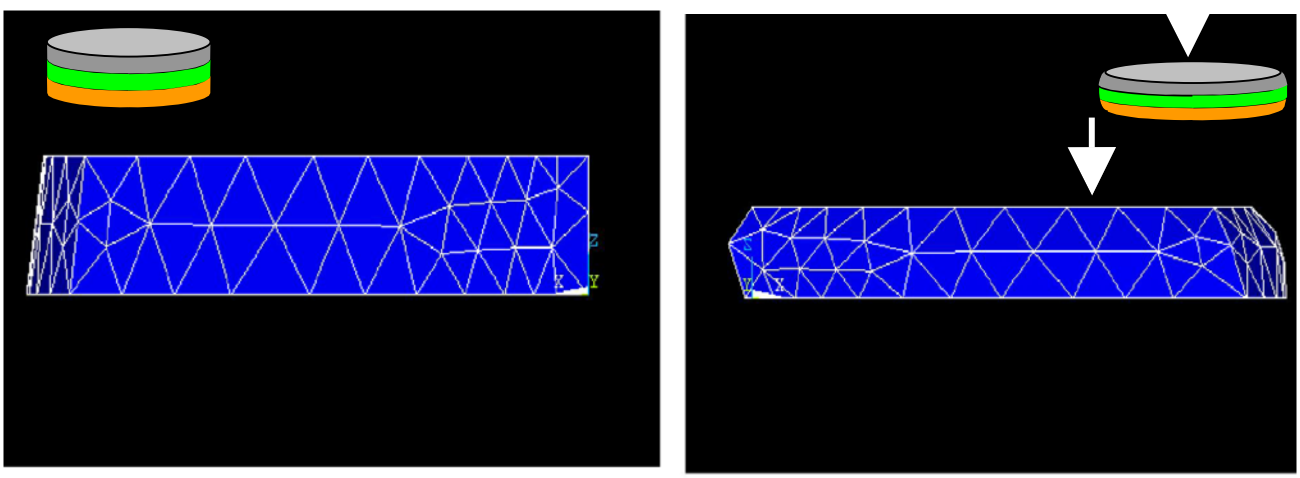
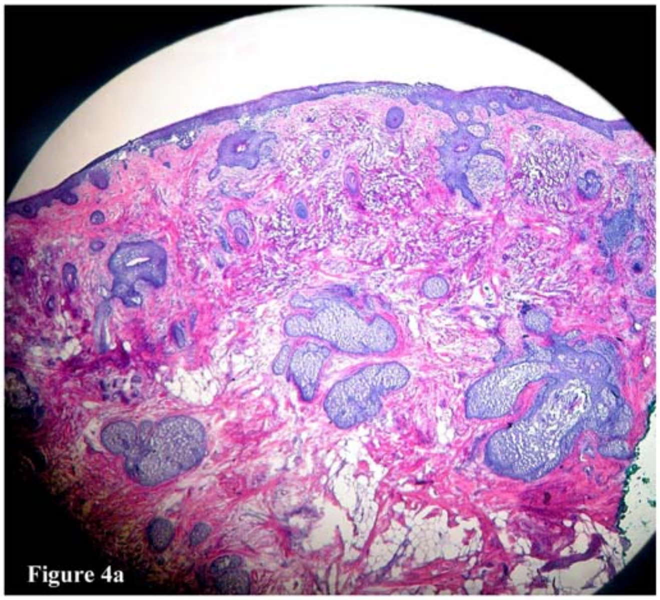


Figure 3: Finite Elements simulation of specimen compression: a calculated model having a taper of 10° before (left hand side) and after the compression (right hand side). Observe a complete layer viewing after the compression as presented both by the finite element model and by the small geometrical illustration (on top).



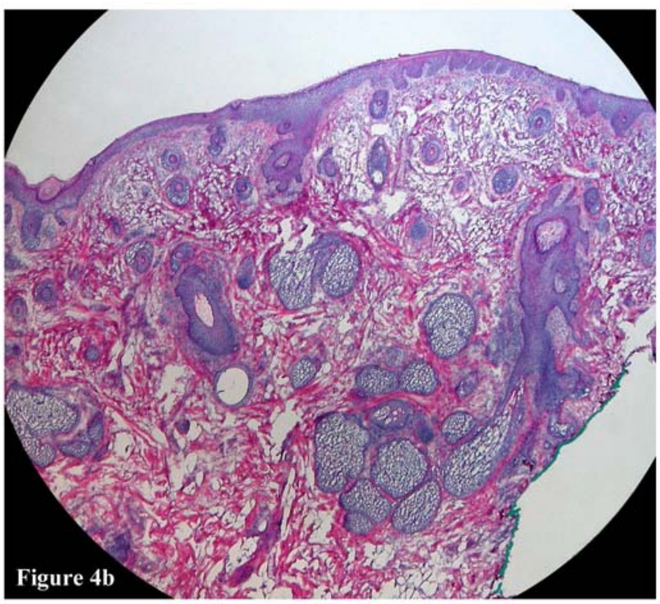


Figure 4: Rapid H & E stained Mohs sections (×4) of a saucer cut with 45° (a), and of an acute angle cut with 10° (b). Both present good layer projection.

Chapter 8

Optimizing the cut in Mohs micrographic surgery in regard to skin sparing and microscopic view: Is a circular incision necessary?

Publication:

Raveh Tilleman T ,Tilleman M.M , Neumann HAM. Optimizing the cut in Mohs micrographic surgery in regard to skin sparing and microscopic view: Is a round incision cut necessary? Accepted to: Clin Exp Dermatol 2004

Presentation:

- XXIII congress of the International Society for Dermatologic Surgery. Porto, September 2002 Portugal.
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- 2nd Annual Research Meeting. General Health Services, Rabin Medical Center, Petach Tikva ,Israel, November 2003.

Abstract

Saucer incision is the common cut in Mohs' micrographic surgery. To date no proof to the superiority of this cut to other patterns has been presented. In this work we examine the round pattern aspect of the saucer incision and answer two questions: does the circular cut provide the best skin-sparing pattern and does it provide the best microscopic view. A two dimensional geometrical analysis is used to determine whether a circular incision is optimal from the standpoint of skin sparing and microscopic view. Mohs' micrographic surgery views are used to backup the geometrical hypothesis.

The result is that the circular incision pattern is skin-wasteful compared with an incision that follows the contour of the cancerous lesion. In the present lesion the two cuts have a ratio of 1.5 between the two excised skin areas, indicating a 50% waste of healthy skin. It is also shown that specimens with a pointed edge provide better layer projection than the circular contour.

The conclusion is that a tailored cut following the lesion pattern is the optimal Mohs incision. Therefore in the first stage of Mohs' micrographic surgery the skin cut should replicate the lesion pattern instead of a circular saucer cut. Although many Mohs surgeons already implement this philosophy, in the literature the saucer incision recommended by Dr. Frederic Mohs remains the norm.

Introduction

Saucer shape excision is the common first layer cut in Mohs' micrographic surgery (MMS) (1). The persistence of Dr. Frederic Mohs saucer pattern excision as a standard is found in various textbooks including general dermatology (2,3), dermatosurgery (4,5) and also in surgery textbooks (6).

The circular cut in the first stage was suggested by Dr. Frederic Mohs (7,8,9). The literature predominantly quotes the saucer incision even when the cancerous tissue drawn or photographed is not circular (2,5,10,11,12). In some publications the drawn cut has rather an oval shape (13,14). However, none of the published patterns exhibits pointed edges such as used in a surgical ellipse.

Considering the microscopic view of a saucer cut, the advantages of a specimen having beveled edge are detailed in previous studies (15,16). On the other hand, the superiority of a circular cut for microscopic view to a pointed edge cut has not been described or proven. In this work we examine the circular pattern aspect of the saucer incision and answer two questions: does the circular cut provide the best skin-sparing pattern and does it provide the best microscopic view.

Materials and Methods

We inspected cutting patterns illustrated by two dimensional geometrical drawings in regard to skin waste and microscopic view. The skin waste of a circular, saucer cut was compared with that of a skin cut following the lesion contour. A rounded excision circumventing the lesion such that the closest points between them are separated by 3 mm was compared with an excision extended only by minimal oncological margins around the lesion (17,18).

In the literature various surrounding margins of normal skin are suggested in order to ensure a complete excision. Some authors suggest 2 mm of excisional margins of non melanoma skin cancer cases presenting clearance of up to 95% (19). Others suggest a 3 mm margin which presents clearance of up to 96% (20, 21). Still other authors found that only 4 mm margins can clear the cancerous tissue up to 96% (22- 25). We chose a 3 mm margin to use in our measurement and in the estimation of skin waste.

A geometrical analysis of the microscopic view for specimens having a pattern with circular and pointed edges was performed. The analysis demonstrates which of the two cuts provides a better layer view. To back up the hypothesis, related microscopic views of frozen sections having a fusiform ellipse pattern, and excised during MMS, are presented.

Results

From the aspect of skin sparing a pattern that follows the skin lesion rather than a circular pattern is preferable, as demonstrated in Figure 1. Shown is an example of Basal Cell Carcinoma with a complex form located on a forehead measuring 14×10 mm. An excision that follows the lesion providing a minimum healthy skin excised is drawn in Figure 1a, compared with a circular cut circumventing the lesion drawn in Figure 1b. The ratio between the two areas is about 1.5, indicating a 50% waste of healthy skin comparing the circular cut to the tailored excision.

As for the aspect of a microscopic view, both specimens with round and pointed edges can achieve good layer projection. The pointed edge, as evidenced at the vertex of a fusiform ellipse, mosque pattern, rhomboid pattern and S-shape incision (26), does not compromise the microscopic view. On the contrary, any pointed edge in the incision offers more information. The radial projection thickness (t) in the outermost layer is shorter than the horizontal thickness (E) at the pointed edge, such that:

$$E = \frac{L}{2}\left\{1 - \sqrt{1 - 2\frac{t}{w}\left[1 + \frac{1}{a^2}\left(1 - 2\frac{t}{w}\right)\right]}\right\}$$

where L and w are respectively the excision length and width, and a is their ratio (= L / w) . Consider for example a fusiform ellipse with a length-to-width ratio of 3:1, L = 30 mm, w = 10 mm and radial projection thickness of 2.5 mm, E becomes 4.7 mm, exceeding by 88% the radial projection thickness t = 2.5 mm.

Frozen sections produced during MMS having a shape of a fusiform ellipse (Figure 2) and its related microscopic views are presented. In Figure 3, a microscopic view of this specimen with a round edge (green margin) and a pointed edge (red margin) is shown. Both edges present a complete layer view. Therefore, a pointed edge presents no difficulty to a microscopic view.

Discussion

In 1936 Dr. Mohs began the clinical use of chemosurgery, originally intended as an in situ fixative on the patient himself (14). At the end of such an operation, the tissue was left untouched until separation took place. No immediate closure or reconstruction was part of the original MMS (27). Therefore, less attention was paid to the original incision shape. In the 1970s a new era of fresh tissue technique began, popularized by Dr. Theodore Tromovitch (28). Subsequently the immediate closure of defects became feasible. This allows for more accurately excised margins, primary repair of the defect, and a more rapid completion of the operation (29). Nowadays, this is the dominant procedure in MMS, thus special attention must be paid to the shape of the excised specimen (30).

In this work we examined the circular pattern aspect of the Mohs saucer incision. It was demonstrated that a tailored cut has two advantages in comparison with a round cut: 1) it is more skin sparing, and 2) it provides a better microscopic view. Therefore, a tailored cut that follows the lesion contour is the optimal Mohs incision.

In conclusion, in the first stage of MMS a skin cut following the lesion pattern should be applied instead of a circular saucer cut. Though many Mohs surgeons already implement this philosophy, in the literature the saucer incision recommended by Dr. Frederic Mohs remains the norm (31).

References

1. Mikhail GR. Techniques in Mohs surgery. Saucerized excision of a disc of tissue. In: Mikhail GR, ed. Mohs micrographic surgery. WB Saundres company 1991;15-6.
2. NPJ Walker, CM Lawrence, RPR Dawber. Dermatological surgery. In: RH Champion, JL Burton, DA Burns SA Brearhnach, eds. Textbook of dermatology. Blackwell Science Ltd, Oxford 1998;3593-623.
3. GJ Hruza, JL Fewkes. Surgery in dermatology. In: TB Fitzpatrick, AZ Eisen, K Wolff, IM Freedberg, KF Austen, eds. Dermatology in general medicine. McGraw-Hill, Inc. 1993;2917-20.
4. Dufresne RG. Mohs surgery: fresh tissue techniques. In: Wheeland RG, ed. Cutaneous surgery. WB Saundres company 1994;880-91.
5. Fewkes JL, Cheney ML, Pollack SV. Mohs' micrographic surgery. In: Fewkes JL, Cheney ML, Pollack SV,eds. Illustrated atlas of Cutaneous surgery. JB Lippincott company New York 1992;29.2-29.12.
6. NA Swanson, TM Johnson. Management of basal cell carcinoma ans squamous cell carcinoma. In: CW Cummings, JM Fredrickson, CJ Krause, LA Harker, DE Schuller, MA Richardson, eds. Otolaryngology head and neck surgery. Mosby 1998;486-501.
7. Steinman HK. Mohs surgical techniques. In: Gross KG, Steinman HK and Rapini RP, eds. Mohs surgery. Fundamentals and techniques. Mosby 1999:49-66.
8. Mohs FE. Chemosurgery for skin cancer: fixed tissue and fresh tissue techniques. Arch dermatol 1976;112:211-5.
9. Tromovitch TA, Beirne G, and Beirne C. Mohs technique (cancer chemosurgery), treatment of recurrent cutaneous carcinomas. Cancer 1966;19:867-8.
10. Shriner D, McKoy DC, Goldberg DJ, and Wagner RF Jr. Mohs micrographic surgery. J Am Acad Dermatol. 1998;39:79-97.
11. Mora RG. Mapping out skin cancer: Mohs micrographic surgery. Virginia medical quarterly, Autumn 1990:361-6.
12. Pearson GL Jr. Mohs micrographic surgery. Fresh tissue technique. Dermatol Clinics 1989;7:613-26.
13. Zitelli JA. Mohs surgery concept and misconcept. .Intl J Dermatol 1985;24:541-8.
14. Picoto AM and Picoto A. Technical procedures for Mohs fresh tissue sugery. J

Dermatol Surg Oncol 1986;12:134-8.

15. Nelson BR, Railan D, and Cohen S: Mohs' micrographic surgery for nonmelanoma skin cancer. Clin Plast Surg. 1997;24:705-18.
16. Raveh Tilleman T, Tilleman MM, Krekels GAM and Neumann MHA. Minimum beveling in Mohs micrographic surgery cut. In: Combined annual meeting ASDS-ACMMSCO. New Orleans 2003.
17. Burg G, Hirsch RD, Konz B, Braun-Falco O. Histographic surgery: accuracy of visual assessment of the margins of basal cell epithelioma. J Dermatol Surg 1975;1:21-4.
18. Ratner D, and Bagiella E. The efficacy of curettage in delineating margins of Basal Cell Carcinoma before Mohs Micrographic Surgery. Dermatol Surg 2003;29:899-903.
19. Lalloo MT, Sood S. Head and neck basal cell carcinoma: treatment using a 2-mm clinical excision margin. Clin Otolaryngol. 2000;25: 370-3.
20. Bisson MA, Dunkin CS, Suvarna SK, Griffiths RW. Do plastic surgeons resect basal cell carcinomas too widely? A prospective study comparing surgical and histological margins. Br J Plast Surg. 2002;55:293-7.
21. De Visscher JG, Gooris PJ, Vermey A, Roodenburg JL Surgical margins for resection of squamous cell carcinoma of the lower lip. Int J Oral Maxillofac Surg.2002;31:154-7.
22. Wolf DJ, Zitelli JA. Surgical margins for basal cell carcinoma. Arch Dermatol.1987;123: 340-4.
23. Thomas DJ, King AR, Peat BG. Excision margins for nonmelanotic skin cancer. Plast Reconstr Surg. 2003;112:57-63.
24. Brodland DG, Zitelli JA. Surgical margins for excision of primary cutaneous squamous cell carcinoma. J Am Acad Dermatol.1992;27:241-8.
25. Breuninger H, Schippert W, Black B, Rassner G. The margin of safety and depth of excision in surgical treatment of basalioma. Use of 3-dimensional histologic study of 2,016 tumors. Hautarzt. 1989;40:693-700.
26. Raveh Tilleman T, Tilleman MM, Krekels GAM and Neumann MHA.,Skin waste, vertex angle and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, rhomboid, mosque and S-shape. Plast Reconst Surg 2004:113:857-861.
27. Mohs FE. Chemosurgery: a microscopically controlled method of cancer excision. Arch

Surg 1941;42:279-295.

28. Tromovitch TA, Stegma SJ.Microscopically controlled excision of skin tumors: chemosurgery (Mohs): fresh tissue technique. Arch Dermatol 1974;110:231-2.
29. Hart V. Mohs' chemosurgery. In: Emmett AJJ and O'rourke MGE,eds. Malignant skin tumors.Longman Group Limited;1982:175.
30. Brodland, D.G., Amonette, R., Hanke, C.W., and Robins, P. The history and evolution of Mohs micrographic surgery. Dermatol Surg. 2000;26:303-7.
31. Robins P. Chemosurgery: my 15 years of experience. J Dermatol Surg Oncol 1981;7:779-89.

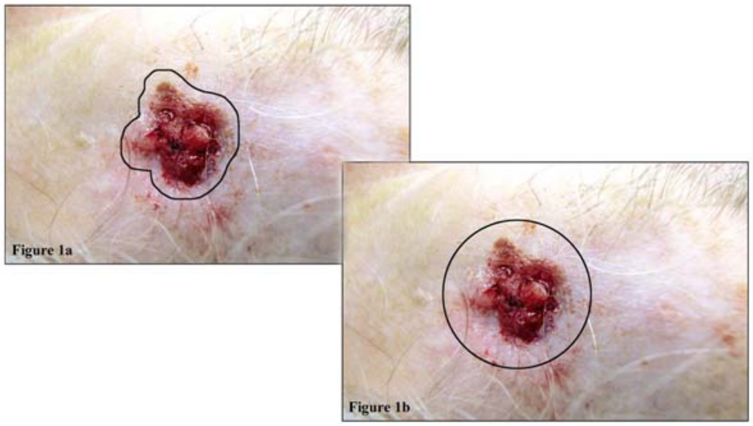
Figure 1a

Figure 1b

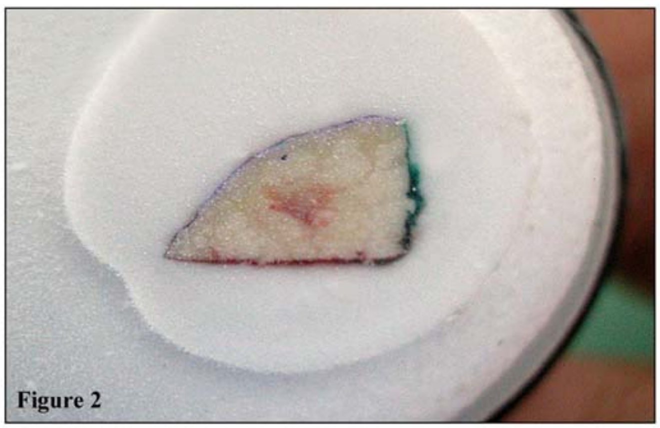
Figure 2


Figure 3

Chapter 9

A new surgical technique for direct closure of circular skin defects without dog-ear excision.

Publication:

Raveh Tilleman T. Direct closure of rounded skin defects. A four-step technique with multiple subcutaneous and cutaneous "figure-of-8" sutures alleviating dog-ears. Accepted for publication by: Plast Reconstr Surg 2004.

Abstract

Excisional biopsies of circular lesions are performed daily by surgeons. A circular excision yields the smallest skin waste and scar length, but presents a surgical challenge in closure due to dog-ear formation. This chapter establishes a surgical technique for direct closure of circular or elliptical defects without producing long scars, skin wasting and dog-ears. A four-step technique based on multiple cutaneous and subcutaneous “figure-of-8” sutures is presented. When correctly placed, those sutures can equally divide excess tissue and alleviate dog-ears.

It is shown that skin can be redistributed, alleviating dog-ears, yielding short scars and saving healthy skin. A significant reduction of the length-to-width ratio and the arc-to-scar length ratio are obtained. In Conclusion a direct closure of a circular or elliptical defect without stipulating a 3:1 length-to-width ratio is feasible. In this technique no excessive healthy tissue is removed and the final scar length is small. The long-term outcome is a thin scar that is linear, flat and concealed in the body structure.

Introduction

Excisional biopsies are daily performed by surgeons for indications varying from esthetic excisions to oncological skin malignancy removal. The purpose of an experienced surgeon is to completely remove the skin lesion while leaving an optimum scar, performing a short operation and accomplish fast healing without complications. Many cutaneous lesions possess a circular or mildly elliptical shapes, yet from a surgical point of view it is a challenge to close a circular defect without creating permanent dog-ears.

The most popular cutting pattern used for excisional biopsies is the surgical ellipse followed by less popular patterns such as the rhomboid, mosque, and S-shape (1). Traditionally the long axis of a surgical ellipse has been at least three times longer than its short axis (2 – 6). This ratio permits avoiding dog-ear formation at the cost of wasting healthy skin tissue and the creation of a long scar (7).

The present surgical technique is a new concept that eliminates the need for any artificial excision pattern. It permits a direct closing a round skin wound while alleviating dog-ears. In four steps this technique enables the closure of any circular or elliptical defect without the need for a 3:1 length-to-width ratio, therefore mitigates undue skin waste. The principle of the present method is that excess tissue can be redistributed provided guiding sutures are placed correctly on the created scar. After several weeks a fine, blunt and concealed linear scar is obtained. The advantage of the present technique is a considerable saving of healthy skin without compromising the quality of the scar.

Surgical technique

The four-step technique for closing circular defects is based on multiple cutaneous and subcutaneous "figure-of-8" sutures that equally divide excess tissue. The first step is excision of the lesion with the recommended oncological margins shown in Figure 1, and performing wide undermining shown in Figure 2. The end result of the first step is an open round wound with skin margins that can be brought together with minimal tension.

The second step is selecting the best line of closure, preferably coinciding with skin lines, such as relaxed skin tension lines (8). The end result of the second step is determining the scar longitudinal axis. Drawn in Figure 3 are the scar axis and some smaller auxiliary, perpendicular lines.

The third step is the closure itself beginning with a row of absorbable, "figure-of-8", buried sutures (Figure 4). The sutures fill two functions: obliterating the dead space of deep margins and starting to equally divide the tissue excess by the mechanism explained below. Photographed in Figure 5 is the end result of the third step: an open wound whose margins are brought together. Observed around the wound is the beginning of wrinkling, pronounced at the scar edges.

The fourth step is the final closure of the epidermis with multiple cutaneous, "figure-of-8" sutures (Figure 6). Note that the wrinkles induced by the suture technique are a byproduct of dog-ear alleviation. The two key sutures are located at the vertices. They intercept at the dog-ear peak, as shown in Figure 13. The peak points can be found by using a skin hook. The pleated scar starts fading within 3 – 4 weeks, and vanishes completely within 3 months. During this period, the scar straightens out, the dog-ears are redistributed and eventually disappear (see Figures 7-12).

Figure 7 shows a circular lesion located on the neck with a lesion size of 15×15 mm. The scar length produced by this closure technique was 24 mm (Figure 8). The same scar after five months shown in Figure 9. Note that the scar is located on a convex surface, indicating that this closure technique is suitable for curved surfaces.

Figure 10 shows an open wound in a paranasal region. The lesion was 7×9 mm and the produced scar length was 11 mm. After two months the resulting scar is hardly noticed (Figure 11). With a similar bearing on the suitability for curved surface, this scar is located on a concave surface. In Figure 12 a scar located on the forearm after six months post operative period is shown. The round lesion was 17×43 mm and the produced scar length was 54 mm.

Observations and Results

Shown in Table 1 are sixty five excisional biopsies taken at the outpatient clinic using the above surgical technique. In the data the aspect ratio is 1:1.45 on the average and the scar length is 53±7% of the arc length. The present aspect ratio is less than a half of the recommended aspect ratio for surgical ellipses (1:3 – 1:4). Mizunuma et al found that a scar length of a surgical ellipse is 92% of the pattern arc (9). In the present work the scar length is only 53% of the arc length, shortening the scar by 40% relative to any other cutting pattern. Consequently, the data indicate a double saving: first, by excising precisely the circular lesion instead of an ellipse, second, by creating a short scar in comparison with the arc length. In sum, this technique offers a shorter scar by a factor of approximately four with respect to a surgical ellipse and less tissue waste by a factor greater than two (1).

Concerning tissue redistribution along the scar, the present technique reduces excess skin at the apex and compensates for skin shortages at the center. On closing an open wound, the apex moves in a rotation manner producing excess skin that forms a vertical cone or dog-ear. At the same time, the central part of the scar advances to cover the longest distance, thus creating tension at the scar center. These trends are even more pronounced if the wound is circular. This takes place because the pseudo-apical angle is 180° and the pattern width is maximal. However, by the present method the stresses around the scar are redistributed. The "figure-of-8" stitch when tightly closed, squeezes tissue between the two loops of the suture (see Figure 13). At the apex the "figure-of-8" suture applies a vertical stress on the dog-ear. Thus the excess skin is distributed forming several smaller, considerably less protruding cones. Around the wound center the "figure-of-8" stitch pulls skin from the horizontal surroundings. Thus while some ripples are formed perpendicular to the longitudinal axis, the scar is contracted. Over time, this lateral stress produces a creeping effect on the scar, which also flattens the dog-ears. Note that the process is limited, because excessive tension of the suture may cause scar ischemia.

An interim effect is a wrinkled scar in the immediate postoperative period. This effect disappears within several weeks yet the patient should be given an educated explanation assuring that the immediate ripple is only temporary.

Over the recent five years of clinical experience, the present technique has proved very safe, reliable and producing good results. Among the main advantages are skin saving and minimal scar length. Follow-ups revealed good cutaneous scars, independent of whether the tissue surface is flat, convex or concave, as presented in Figures 7-12.

Discussion

Many skin lesions are circular, yet the applied excision pattern is often different given skin wasteful shapes, such as the surgical ellipse. Surgeons do not simply cut a circle around the lesion to remove it, even though a circular cut removes less skin and leaves a shorter scar than any other skin excision, as shown in Chapters 2, 3 and 4. The reason is that a circular excision does not stitch very well when directly closed. It leaves an elevated skin bunched up at the ends, namely a "dog-ear".

The objective of this study was to develop a surgical technique for closing circular defects without removing healthy tissue while solving the dog-ear problem. This method could be realized owing to numerous clinical observations about the skin ability to redistribute. For example: skin, which has been strained by tension, relaxes over time (2). A small circular excision cut by a punch biopsy allows primary closure without future noticeable dog-ears (10). Some dog-ears flatten spontaneously due to contraction of the linear scar both longitudinally and vertically (11). Closing a wound of unequal sides can be accomplished by the "rule of halves" where the excised skin of the longer side is equally divided without forming a dog-ear (12). In the Z-plasty technique the surgeon induces a better scar by borrowing skin from a zone with excess skin to a zone with a shortage (13). This elongates one axis and shortens the other. Over time the stretched skin in one area and the shrunk skin in the perpendicular area relax.

All of the above are examples of the skin ability to redistribute, where one of the most prominent observations of this ability is in the vertical reduction mammoplasty. In order to avoid horizontal inframammary scar, a wrinkled, shrunk vertical suture is performed (14). Subcuticular running suture can reduce the vertical subareolar length by 50% or more (15) resulting in fine wrinkling around the vertical scar that vanish over time. These examples were the basis for the present suture technique. By forcing the skin to redistribute, a short scar is formed, with some temporary wrinkles that disappear within several weeks. The excess skin that would otherwise form dog-ears is equally divided along the scar. A pivotal advantage of this technique is in saving healthy skin without compromising the scar quality or the healing process.

This technique has been established for any surface topography. It has good results for concave, convex or flat surface as shown in the figures. It is also a solution for alleviating a dog-ear created during flap movements. Though at the pivot of a rotation flap a dog-ear is created (16) and at the base of an advancement flap excess skin folds (Bürow's triangles) are formed (17), by applying the present suture technique the excess tissue can be immediately corrected without any healthy skin removal and without creating additional scars and backcuts.

This technique is suitable for many surgeons who previously ignored the circular cut fearing the creation of unpleasant wrinkled scars and dog-ears. It is also an alternative to the axiomatic use of surgical ellipse for skin biopsies.

To conclude, a direct closure of a circular or elliptical defect without stipulating a 3:1 length-to-width ratio is feasible. The immediate outcome is saving of healthy skin tissue. A byproduct of skin sparing is a significant reduction of the scar length. The described suture technique prevents the formation of dog-ears during excisional biopsies. It is also a method relaxing the excess of tissue created at the pivot of a rotation flap, or the excessive triangles during advancement flap. This technique is used daily at our practice yielding good results. The long-term outcome is a thin scar that is linear, flat and concealed in the body structure.

References

1. Raveh Tilleman T, Tilleman M.M, Krekels GAM and Neumann HAM. Skin waste, vertex angle and scar length in excisional biopsies. Comparing five excision patterns: fusiform ellipse, fusiform circle, rhomboid, mosque and S-shape. Plast Reconst Surg 2004;
2. Grabb WC. Basic techniques in plastic surgery. In: Grabb WC, and Smith JW, eds. Plastic surgery. A concise guide to clinical practice. Little, Brown and Company, Boston 1973;3-74.
3. Wood RJ and Jurkiewicz. Plastic and reconstructive surgery. In: Schwartz SI, Shires GA, Spencer FC, Daly JM, Fischer JE, and Galloway AC, eds. Principles of surgery seventh editon. McGraw Hill 1999;2091-143.
4. Length of scar and the "dog-ear". In: McGregor IA, ed. Fundamental techniques of plastic surgery and their surgical applications. E & S Livingstone Ltd. Edinburgh and London 1960;31.
5. Ellipse. In: Stegman SJ, Tromovitch TA, and Glogau RG,eds. Basics of dermatologic surgery. Year Book Medical Publishers, Inc. Chicago, London 1982;60-68.
6. Rohrich RJ and Robinson JB. Wound healing. Selected Reading 1999;9:1-39.
7. Raveh Tilleman T, Tilleman M.M, Smeets N, and Neumann HAM. Skin waste in elliptical excision biopsies . Accepted to the Scand J Plast Reconstr Surgery Hand Surg 2004.
8. Borges AF. Relaxed skin tension lines (RSTL) versus other skin lines. Plast Reconstr Surg 1984;73:144-50.
9. Mizunuma M, Yanai A, Tsutsumi S, Yosida H, Seno H, Inoue M, and Nisbida M. Can dog ear formation be decreased when an s shape resection is used instead of spindle skin resection? A three dimensional analysis of skin surgery techniques using finite element method. Plast Reconstr Surg. 2000;106:845-8.
10. Schultz BC. Skin biopsy. In: Roenigk RK, and Roenigk HH,eds. Dermatologic Surgery Principles and practice. Marcel Dekker Inc, New York, Basel 1989;139-154.
11. Complex closure. In:Bennett RG,ed. Fundamentals of cutaneous surgery. The C.V. Mosby Company 1988;473-91.

12. Dog-ear repair and closure of sides of unequal lenth. In: Stegman SJ, Tromovitch TA, and Glogau RG,eds. Basics of dermatologic surgery. Year Book Medical Publishers, Inc. Chicago, London 1982;69-72.
13. Furnas DW and Fischer GW. The Z- plasty: biomechanics and mathematics. Br J Plast Surg 1971:144-160
14. Lassus C. A 30-year experience with vertical. Plast Reconstr Surg 1996;97:373-80
15. LeJour M. Vertical mammaplasty: update and appraisal of late results. Plast Reconstr Surg 1999;104:771-81
16. General considerations. In: Jackson TI,ed. Local flaps in head and neck reconstruction. CV Mosby 1985;1-34
17. Bardach J, Levine NS, Buchanan RT, Cohen M and Marschall MA. Surgical techniques using local flaps in head and neck reconstruction. In: Bardach J,ed. Local flaps and free skin grafts. CV Mosby 1992;87-126

Table 1: Sixty five cases of excisional biopsies and wound closure using the present technique. The units are in millimeters.

location	scar length	Width	length	length/ width	arc	scar/arc
back	22	8	14	1.75	34.56	0.64
back	17	8	12	1.50	31.42	0.54
abdomen	23	11	17	1.55	43.98	0.52
hand	33	16	22	1.38	59.69	0.55
face	28	16	15	0.94	48.69	0.58
face	17	9	11	1.22	31.42	0.54
leg	9	4	5	1.25	14.14	0.64
back	21	8	14	1.75	34.56	0.61
back	17	8	12	1.50	31.42	0.54
neck	23	11	17	1.55	43.98	0.52
neck	24	15	15	1.00	47.12	0.51
neck	38	18	25	1.39	67.54	0.56
chest	39	19	23	1.21	65.97	0.59
hand	54	17	43	2.53	94.25	0.57
axilla	52	16	33	2.06	76.97	0.68
face	21	15	17	1.13	50.27	0.42
back	25	14	18	1.29	50.27	0.50
back	39	22	32	1.45	84.82	0.46
face	35	16	16	1.00	50.27	0.70
leg	29	12	21	1.75	51.84	0.56
gluteus	18	5	12	2.40	26.70	0.67
leg	21	9	16	1.78	39.27	0.53
face	31	11	25	2.27	56.55	0.55
chest	17	9	13	1.44	34.56	0.49
face	25	11	21	1.91	50.27	0.50
face	19	7	16	2.29	36.13	0.53
back	23	13	19	1.46	50.27	0.46
face	20	9	14	1.56	36.13	0.55
back	23	13	19	1.46	50.27	0.46
face	20	9	14	1.56	36.13	0.55
back	30	18	22	1.22	62.83	0.48
back	36	19	25	1.32	69.12	0.52
arm	17	8	12	1.50	31.42	0.54
back	32	17	29	1.71	72.26	0.44
back	52	31	39	1.26	109.96	0.47
face	11	7	9	1.29	25.13	0.44
back	20	9	13	1.44	34.56	0.58

location	scar length	Width	length	length/ width	arc	scar/arc
back	17	8	13	1.63	32.99	0.52
face	22	13	15	1.15	43.98	0.50
face	21	11	15	1.36	40.84	0.51
neck	20	10	11	1.10	32.99	0.61
face	20	9	14	1.56	36.13	0.55
face	9	4	6	1.50	15.71	0.57
face	33	19	29	1.53	75.40	0.44
face	14	7	10	1.43	26.70	0.52
leg	19	11	15	1.36	40.84	0.47
finger	29	10	16	1.60	40.84	0.71
face	18	9	12	1.33	32.99	0.55
face	42	22	29	1.32	80.11	0.52
neck	30	15	21	1.40	56.55	0.53
face	17	12	15	1.25	42.41	0.40
face	32	20	28	1.40	75.40	0.42
face	15	7	10	1.43	26.70	0.56
leg	20	9	10	1.11	29.85	0.67
face	13	7	10	1.43	26.70	0.49
leg	13	7	10	1.43	26.70	0.49
abdomen	16	8	11	1.38	29.85	0.54
chest	18	10	12	1.20	34.56	0.52
chest	15	11	13	1.18	37.70	0.40
back	21	10	13	1.30	36.13	0.58
back	18	11	11	1.00	34.56	0.52
face	12	10	11	1.10	32.99	0.36
leg	25	15	19	1.27	53.41	0.47
back	14	10	11	1.10	32.99	0.42

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6


Figure 7


Figure 8

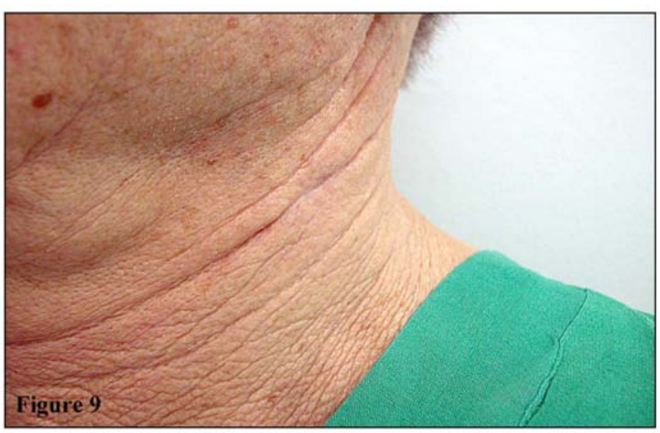
Figure 9

Figure 10

Figure 11

Figure 12


Figure 13

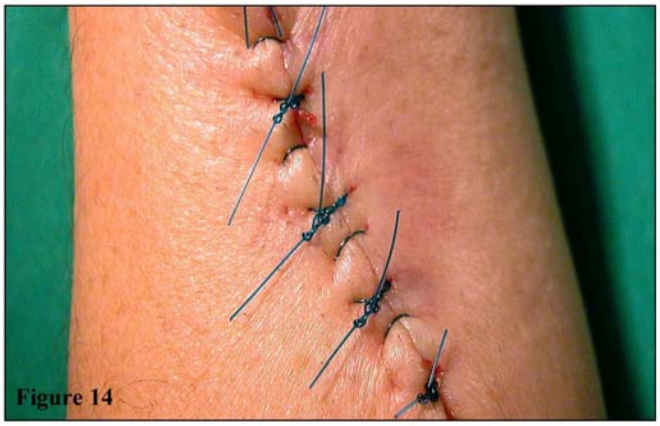
Figure 14

Chapter 10

Summary and Conclusions

In chapter 1, a general introduction into the rationale of surgery and various techniques for cutaneous excisional biopsies and repairing the defects were described. In the studies described in chapter 2, the most economical patterns with regard to extra skin waste, scar length and vertex angle were investigated. A comparison of minimum waste area showed that the best patterns were the rhomboid and the mosque excision. The second comparison of the scar length showed that the length was almost independent of the pattern. The third comparison showed that the rhomboid and the S-shape patterns possessed the smallest vertex angles and thus minimized the formation of dog ear. Interestingly, the common surgical ellipse was observed not to have any advantage in any of the cut pattern categories.

The currently held paradigm that the vertex angle of a surgical ellipse should be 30° or less for length-to-width ratios of lower than 4 was found to be mathematically incorrect. The circular excision pattern, i.e. a direct excision of a round lesion, was found superior to other patterns that were examined in that there was no skin waste and that the resulting scar length was the shortest. However, the circular excision had the highest vertex angle (180°), which resulted in large dog ear formation during closure.

The present paradigm of surgical ellipse dimensions was also observed to be incorrect from the clinical point of view which was noted in studies described in chapter 3. The relation of length-to-width ratio and vertex angle of ellipses cited in the literature and in our own outpatient clinical cases proved that within the commonly used range of length-to-width ratio of 3 to 4, the vertex angle was between 67º to 48º, but never reached the assumed value of 30º. It was also shown that the length-to-width ratios in those data were shorter than the recommended 4, with an average of 3.1 in the published studies and 2.5 in our clinical studies.

The amount of healthy skin that was wasted in surgical ellipse biopsies was quantified in studies described in chapters 4 and 5. A large amount of tissue wastage was observed to occur both in malignant and benign lesions and in small and large lesions for the purpose of producing a linear scar and avoiding dog-ear formation. The measured skin wastage varied between 57% and 733% relative to the lesion area. Therefore, the surgical ellipse was found to be an unnecessary cutting pattern. It is recommended that the ellipse pattern should be replaced by a circular excision for suspected malignant lesions and a shave biopsy for benign lesions in order to minimize skin wastage and scar formation.

The elastic properties of frozen and cancerous skin specimens were investigated in the studies described in Chapter 6. The elastic constants were measured resulting in a Poisson's ratio of 0.43 ± 0.12 and a Young's modulus of 52 ± 45 KPa. Defining the elastic properties of the cancerous skin allowed us to use a finite elements analysis (ANSYS) in subsequent investigation into the clinical simulation of tissue compression in a cryostate during the preparation of frozen sections.

The current paradigmal cut used in Mohs' micrographic surgery, the saucer incision, was noted to have disadvantages in the next two studies. In studies described in Chapter 7, using the finite elements method, it was observed that a taper of 10° was the minimum beveling which still permitted projection and viewing of all the skin layers after the cryostat compression. Therefore, it may be applied instead of the commonly used 45° taper.

The studies described in Chapter 8 demonstrated that a cutting pattern that followed the lesion contour rather than the circular cut had two advantages: it was more skin sparing and provided a better microscopic view. Therefore, an alternative to the saucer incision that has been used for 80 years, since the first day the Mohs' micrographic surgery was undertaken, is presented. It is a tailored cut following the shape of a lesion with a taper of 10°.

The findings of the studies described in the chapters 2 to 8 showed that the surgical ellipse cut was inferior to the circular excision pattern which was superior in terms of skin sparing and scar length. In the studies described in Chapter 9, an attempt to overcome the only disadvantage of the circular excision, namely the dog-ear formation during closure, was pursued. The surgical paradigm that a direct closure of circular defects is not feasible without additional surgical manipulation or excisions was observed to be inaccurate. The study provided a new surgical technique permitting a direct closure of circular defects with no loss of healthy tissue and with a solution for the problem of dog-ear. The sparing of healthy skin significantly reduced the length of the scar without compromising the quality of the scar and the healing. This technique may be applied after a circular excision of cutaneous lesions or in the last round of Mohs' micrographic surgery.

The studies exploring paradigms in cutaneous surgery described in this thesis showed that three paradigms were incorrect and provided two new surgical techniques: one for general cutaneous surgery and another for Mohs' micrographic surgery, as alternatives to obtain optimum therapy and esthetic outcome for the patient.

There are several innovations in the present work. First, it introduces new methods to the surgical research. They include rigorous mathematical and engineering tools, unbiased by doctrine or surgeon's experience, enabling accurate quantitative criteria to assess the effectiveness of surgical cuts. For instance, by using these methods the parameters of skin wastage, scar length, beveling angle and vertex angle were explored. Second, optimization of cutting patterns was accomplished by defining a set of parameters. Optimized patterns were thus found in regard to skin wastage, scar length, good microscopic view and esthetic results. Third, factors which were not of prime importance heretofore received additional attention, and were perhaps brought to the forefront of considerations in cutaneous surgery. An example of such parameter is the preservation of healthy skin. Fourth, a new surgical method was established for the closure of circular cuts without dog-ear formation. Fifth, based on our measured finding of the elastic properties of cancerous skin, a novel Mohs' cut was developed.

The present systematic pursuit of accurate, optimal cutting patterns and new surgical techniques offer a contribution to the doctrine of surgery. It adds a new aspect also to EBM in the context of cutaneous surgery, whereby contemporary research tools may become one of the criteria in the designing and performing of operations.

Samenvatting en Conclusies

Hoofdstuk 1 is een algemene introductie over de grondgedachten van chirurgie en de verschillende voor handen zijnde technieken voor het verrichten van excisies/biopten en het herstellen van huiddefecten. In hoofdstuk 2 beschreven studies worden de meest economische technieken onderzocht in verband met het potentieel en nodeloze verlies van gezonde huid, in relatie tot littekenlengte als in de relatie tot de longitudinale as hoek (toppunt). Bij een vergelijking van het minimaal verloren huidgebied blijkt dat de beste excisie patronen de romboidaal en de "moskee" excisies zijn. Een tweede onderzoek betreft de vergelijking van de lengte van het litteken. Hierin wordt aangetoond dat deze lengte bijna onafhankelijk is van het patroon van de excisie. Een derde vergelijking laat zien dat de romboidaal en de S-vormige patronen de kleinste hoeken aan de longitudinale as hebben waardoor het ontstaan van een zogenaamd "hondenoor" geminimaliseerd wordt. Interessant is het feit dat de algemene chirurgische ellips, welke zoveel wordt toegepast, geen enkel voordeel heeft ten opzichte van de vele andere mogelijkheden van een excisie vorm. Het huidige paradigma dat de longitudinale as hoek van een chirurgische ellips 30° of minder moet bedragen bij een lengte/breedte ratio van minder dan 4, is wiskundig onjuist gebleken. De cirkelvormige excisie, dat wil zeggen een excisie van een ronde laesie, welke deze vorm direct volgt, blijkt superieur te zijn in vergelijking met de andere onderzochte vormen omdat het nodeloze huidverlies hierbij minimaal is en omdat de resulterende littekenlengte korter is dan bij alle andere vormen. De cirkelvormige excisie had echter de hoogste longitudinale hoek (180°), waardoor een groot hondenoor ontstaat bij het primair sluiten van deze wond.

Het huidige geldende paradigma over de afmetingen van de chirurgische ellips wordt beschreven en onderzocht in Hoofdstuk 3. De conclusie is dat dit paradigma klinisch onjuist blijkt te zijn. De relatie van lengte tot breedte en longitudinale as hoek van de ellips, zoals vaak in de literatuur geciteerd wordt en eveneens veel toegepast wordt bij onze patiënten, bewijst dat binnen de algemeen toegepaste verhouding van lengte tot breedte van 3 tot 4 waarbij de longitudinale hoek tussen 67º tot 48º bedraagt. Deze hoek bereikt echter nooit de algemeen aanvaardbare waarde van 30º. Tevens wordt gezien dat de lengte / breedte ratios minder zijn dan de aanbevolen 4, met een berekend gemiddelde van 3,1 van uit de gepubliceerde studies en zelfs slechts 2,5 bedraagt in onze eigen klinische studies.

Het ongewenste verlies van gezonde huid bij de chirurgische ellips wordt besproken in de Hoofdstukken 4 and 5. Om zowel een lineair litteken te verkrijgen en tevens een hondenoor te vermijden gaat een grote hoeveelheid gezond weefsel verloren. Dit ongeacht of het een maligne dan wel een benigne tumor betreft. Dit is bovendien onafhankelijk van de grote van de tumor. Het gemeten huidverlies varieert tussen de 57 en 733% afhankelijk van de omvang van de laesie. Daarom wordt de chirurgische ellips als een weefsel verspillende en dus onnodig snijpatroon aangemerkt. Aanbevolen wordt de ellips te vervangen door een cirkelvormige excisie bij (verdachte) maligne tumoren en een shavebiopsie voor goedaardige tumoren om zodoende onnodig huidverlies en de vorming van het litteken te minimaliseren.

De elastische eigenschappen van bevroren maligne huidtumoren werden onderzocht en de resultaten van dit onderzoek wordt vermeld in Hoofdstuk 6. De elasticiteits karakteristieken werden gemeten en blijken een Poisson's ratio van 0,43 ± 0,12 en een Young's modulus van 52 ± 45 Kpa te bezitten. Het definiëren van de elastische eigenschappen van deze monsters maakte het mogelijk om een beperkte element analysis (ANSYS) toe te passen in een vervolgonderzoek naar de klinische simulatie van weefsel compressie in bevroren staat tijdens het maken van vriescoupes.

Het huidige paradigma, de 45º snede, ook wel genoemd de schotelincisie welk gebruikt wordt in Mohs' micrografische chirurgie, bleek in de volgende twee studies nadelen te hebben. In het onderzoek vermeldt in Hoofdstuk 7, wordt gebruik gemaakt van de finite elements method, waarbij wordt waargenomen dat een hoek van 10° het minimum is voor een goede projectie om alle huidlagen na compressie in de cryostat in één coupe te verkrijgen. Daarom kan deze hoek beter gebruikt worden bij het verrichten van een Mohs snede en is de algemeen gebruikte hoek van 45°, die bovendien lastiger bij de patiënt uit te voeren is, niet nodig.

De studies beschreven in Hoofdstuk 8 tonen aan dat het snijpatroon welke de natuurlijke vorm van een huidlaesie volgt, in plaats van een zuivere cirkelvormig snede twee voordelen heeft: 1.) het bespaart meer gezonde huid en 2.) het geeft een beter microscopisch beeld. Daarom wordt een alternatief voor de schotelincisie, welke al 80 jaar gebruikt wordt, namelijk sinds the eerste dag dat Frederik Mohs deze operatie uitvoerde, gepresenteerd. Het is een aangepaste snede (incisie) welke de vorm van de laesie direct volgt met een snijhoek van 10°.

De resultaten van de onderzoeken beschreven in de Hoofdstukken 2 tot 8 laten zien dat de chirurgische ellipsexcisie inferieur is aan het cirkelvormige excisie patroon omdat de cirkelvormige excisie meer gezonde huid spaart en een korter litteken oplevert. In het onderzoek in Hoofdstuk 9, wordt een poging gedaan om het enige nadeel van de cirkelvormige excisie, namelijk het ontstaan van een hondenoor tijdens de primaire sluiting, te voorkomen. Het chirurgische paradigma dat een primiare sluiting van ronde defecten niet haalbaar zou zijn zonder aanvullende chirurgische manipulatie blijkt onjuist te zijn. Dit onderzoek leidde tot een nieuwe chirurgische techniek, welke een primaire sluiting van ronde defecten mogelijk maakt zonder nodeloos verlies van gezond weefsel en tevens een oplossing geeft voor het probleem van het ontstaan van een het hondenoor. Het sparen van gezonde huid verkleint bovendien in belangrijke mate de lengte van het litteken zonder het optreden van verlies van kwaliteit van het litteken en de genezing ervan. Deze sluiting kan gebruikt worden na een cirkelvormige excisie van een cutane laesies maar ook bij de laatste ronde van operatie volgens de Mohs' micrografische chirurgische techniek.

De oriënterende onderzoeken naar paradigma's in cutane chirurgie zoals beschreven in dit proefschrift laten zien dat drie paradigma's onjuist blijken te zijn. Twee nieuwe chirurgische technieken (één voor algemene cutane chirurgie en de andere voor Mohs' micrografische chirurgie) zijn naar aanleiding van de resultaten van dit onderzoek ontwikkeld als alternatieven met het doel optimale therapie met eveneens een optimaal esthetisch resultaat voor de patiënt.

In dit proefschrift worden verschillende innovaties gepresenteerd. Ten eerste de introductie van nieuwe technieken voor onderzoek op het vakgebied chirurgie. Dit betreft ondermeer uitgebreide mathematische constructieve hulpmiddelen, zonder beinvloeding van doctrines of ervaringsfeiten van de chirurg. Hiermee kunnen nauwkeurige kwantitatieve kriteria gegeven worden voor de effectiviteit van bepaalde chirurgische sneden. Bij voorbeeld kon met deze methoden de parameters van huidverlies, litteken lengte, snijhoek en longitudinale as hoek worden onderzocht. Ten tweede, het optimaliseren van snijpatronen wordt tot stand gebracht door een groep parameters te definiëren. Optimale patronen konden zodoende vastgesteld worden met betrekking tot huidverlies, littekenlengte, optimaal microscopisch beeld en het cosmetisch resultaat. Ten derde, factoren welke niet van doorslaggevend belang zijn voor het primaire doel kregen additionele aandacht en worden naar het voorste front gehaald in de overwegingen voor cutane chirurgie. Een voorbeeld van een degelijke parameter is het sparen van gezonde huid. Ten vierde werd een nieuwe chirurgische methode ontwikkeld voor het sluiten van een rond deffect zonder de nadelen van optredende hondeoren. Ten vijfde kon door de elastische karakteristieken van huidtumoren te bepalen een nieuwe Mohs' snede worden ontwikkeld. De huidige systematische opeenvolging van een optimaal snijpatroon en nieuwe heelkundige technieken, leveren een bijdrage aan de chirurgische leer.

Het voegt nieuwe aspecten toe aan het abc van de chirurgie in de context van cutane chirurgie, waarbij hedendaagse onderzoekstechnieken mogelijk één van de criteria zal worden voor het ontwikkelen en uitvoeren van operaties.

Dankwoord and acknowledgements

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I am grateful to Professor Fernando Ortiz Monasterio, a renowned innovator of many techniques in plastic surgery. He showed me that reconstructive plastic surgery is both magical and enjoyable. He set an example for pioneering scientific work, contribution to the community, and hard work for the benefit of humankind.

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Special thanks to Professor Martino Neumann, who taught me the principles of the Mohs Micrographic Surgery and conceived the idea of this thesis. Professor Neumann encouraged me to speak up my mind in matters of the medical science, being directed by my conscience and professionalism. Without his support this work would not have come to fruition.

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Special thanks go to a special person: my husband Doctor Michael Tilleman. He is a brilliant gentleman, an intellectual, a talented scientist and a warm person. Life and research by joint scientific work with him become straightforward, enriching, amazingly challenging and fun. His contribution to this work, with mathematical and engineering tools, is countless. In addition I thank him for the endurance and sleepless nights.

Last but not least, I want to dedicate this work to my many patients during fourteen years of surgery, from whom I learn every day and am empowered by.

Curriculum Vitae

Tamara Raveh Tilleman was born on August 18^{th} 1959 in Tel Aviv, Israel. During her school years she played basketball in the youth national league teams and simultaneously was active in the youth council of Tel Aviv. There she was elected chairperson for two years, deputy of the youth city of Tel Aviv and Mayor of the youth city of Tel Aviv (1976 – 77).

Tamara earned four academic degrees: 1) Doctor of Medicine from Tel Aviv University, 2) Bachelor of Arts (cum laude) in Economics from Hebrew University, Jerusalem, 3) Bachelor of Science from Hebrew University, Jerusalem, and 4) Master's diploma in Plastic Surgery from Tel Aviv University.

Her professional experience includes: 1) Surgery resident at Tel Aviv Medical Center, 2) Plastic Surgery resident at Hadassah Medical Center, Jerusalem, 3) Research fellowship at V.A. Hospital in NY University, New York, 4) Esthetic and Reconstructive Surgery fellowship at Hospital Angeles, Mexico City, Mexico, and 5) Mohs' Micrographic Surgery fellow at AZM Hospital Maastricht, The Netherlands. In addition, Dr. Raveh Tilleman is a trained Advanced Trauma Life Support (ATLS) Instructor of the American College of Surgeons.

Tamara Raveh Tilleman is a board certified Plastic Surgeon, a Mohs' surgeon and is the head of the Mohs' Micrographic Surgery Unit at Rabin Medical Center, Israel.
She has published fourteen papers in peer reviewed medical journals and presented seventeen papers at international conferences. Tamara is a member in the following Societies: the American Society of Plastic Surgery, the Israel Society of Plastic Surgery, the Israel Society of Dermato-Surgery and the European Society of Mohs' Surgery.

Tamara is deeply involved in voluntary activities in Israel including having established a breast cancer clinic at Neve-Tirza female prison and running it during the years 1993-2003, volunteer in the Israeli Defense Forces as an ATLS instructor. She currently operates an internet consultation column on skin cancer treatment at: http://www.ynet.co.il/home/0,7340,L-2227-14825,00.html

Tamara is married to Dr. Michael M Tilleman, PhD, a scientist, engineer and inventor.

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