WOUND CLOSURE

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Successful wound closure depends on many factors that must be understood and evaluated when accessing the patient's ability to heal uneventfully. These factors include an assessment of the health and nourishment of the patient, along with a thorough medical history to pinpoint any previous problems with healing. This will allow the surgeon to be prepared for alternative material and techniques in the presence of factors that will delay healing. The presence of infection is one of the main reasons for delayed wound healing. In addition to poor physical condition, diabetes mellitus, certain medications such as steroid therapy, older age, and capillary oozing all contribute to a delayed host response to healing. Sutures and the newest techniques cannot compensate for these abnormalities at the patient's cellular level, but by understanding each patient individually, the surgeon will be able to make the proper selection of material and technique for the least complicated wound closure.

SUTURE CHARACTERISTICS

There are two basic types of suture materials, absorbable and nonabsorbable. Absorbable sutures can be further divided into surgical gut (natural) sutures and synthetic absorbable sutures. Surgical gut sutures are made from animal tissues and are digested and absorbed by tissue enzymes and phagocytes. Synthetic absorbable sutures are made from materials, such as polyglycolic acid (PGA), PGA and lactic acid, glycolic acid and trimethylene, or polydixoamone. These sutures are absorbed by the process of hydrolysis, which means that the material is broken down by contact with body fluids. There are a variety of different types of nonabsorbable sutures available, including silk, cotton, synthetic nylon, polyester, polypropylene and stainless steel. Synthetic materials such as silk, nylon, or cotton may fragment or break down in the body after a long period of time. Polyester, polypropylene and stainless steel are far less likely to break down in the body. Nonabsorbable sutures in the skin are normally removed while those within the body in deeper tissues become encapsulated.

The absorption process of absorbable sutures is manifested by a gradual, almost linear loss of tensile strength over the first few weeks following implantation within the body. This gradual decline is followed by the second stage of absorption with loss of suture mass. During the breakdown process, leucocytic cellular responses occur that serve to remove cellular debris as well as suture material from the line of suture tissue approximation. (See table 1 for types of suture materials and construction.)

SUTURE SIZE

Sutures range in sizes from 7, the largest, to 11-0, the smallest. Sutures in the larger diameters from 7 to 2 are usually used as retention sutures. Those in the 1, 0, 2-0 - 4-0 diameter are usually used in general surgery closure. Most frequently, the 2-0, 3-0, 4-0, 5-0, 6-0, and 7-0 diameter sutures are used in plastic/cuticular and fascial layer/tendon surgery. Diameters of 6-0, 7-0, 8-0 up to a 11-0 diameter are used frequently in microsurgical/opthalmic surgery. The diameter of sutures is standardized by the United States Pharmacopeia.

Sutures are made either as monofilament or multifilament. Monofilament consists of a single suture filament and is known for its smoothness through tissue. Multifilament consists of a number of strands braided or twisted together. Multifilament sutures are known for their handling properties.

Polyglycolic acid sutures are treated with poloxamer 188, which acts to reduce friction,

TABLE 1

NONABSORBABLE SUTURES

Generic Name	Trade Name	Construction
Nylon	Dermalon (monofilament)	Uncoated monofilament nylon
	Surgilon (multifilament)	Braided nylon fibers with silicone coating
	Ethilon	Polyamide polymer
	Nurolon	Polyamide polymer
Polypropylene	Surgilene (monofilament)	Monofilament of linear hydrocarbon polymer
	Prolene, Supramid, Deklene	Polymer of Propylene
Polybutester	Novafil (monofilament)	A copolymer (84% polymer) Poly (butylene) terephthalate (16% polymer) tetramethylene ether gycolterephthalate
	Prolene	
Polyester (coated)	TICRON silicone-treated fiber, braided, Polydek	Braided polyester fibers
	Ethibond, Tevdek	Polyester polyethylene terephthalate coated with polybutilate
Polyester (uncoated)	Braided mulitfilament	
	Dacron	Uncoated polyester fiber
	Mersilene	Polyester polyethylene terephthalate
Stainless Steel	Monofilament, Ethicon monofilament and multifilament stainless steel	Ferrous Alloy
	Flexon (multistrand)	Twisted multistrand of Ferrous Alloy

ABSORBABLES

Surgical Gut plain, mild chromic, chromic gut	D&G surgical gut	Protein acesous sheep or beef intestine lining
	Ethicon surgical gut, Deknatel surgical gut	Collagen derived from healthy animals
Synthetic absorbables	Coated Dexon Plus (multifilament)	Same as Dexon S with a Polaxamer 188 coating
	Coated Vicryl	Copolymer of lactide & glycolide coated with polygalactin 370 & calcium sterate
	PDS	Polyester polymer
	Dexon S (monofilament)	Glycolic Acid homopolymer
	Uncoated Vicryl	
	Vicryl (monofilament)	
	Dexon S (multifilament)	
	Maxon (monofilament)	Monofilament strand of 67% PGA & 33% trimethalene carbonate
Silk	D&G silicone treated	
	Ethicon silk	Raw silk
	Deknatel silk	

allowing the sutures to be pulled through tissue more easily. Treated or chromic gut undergoes treatment in a chromium salt solution which allows the suture to resist body enzymes, prolonging absorption time over 90 days. Plain gut is digested within 7 to 10 days. Plain gut may be utilized in tissues which heal rapidly, such as superficial blood vessels. Most suture materials do not improve the rate of normal wound healing and in fact they may cause tissue reaction. A foreign body response to the suture material may occur and consideration must be given to the type of material and site of implantation to minimize the likelihood of this response.

FREQUENTLY USED SUTURES

POLYGLYCOLIC ACID SUTURES AND POLYGLACTIN 910.

Polyglycolic acid (Dexon) is a synthetic homopolymer of glycolic acid. Because it is a man made material, the suture strands contain no collagenous protein, antigens or pyrogens. Less tissue reaction and inflammation lead to less patient discomfort during healing. This is in contrast to surgical gut which is likely to cause greater tissue reaction. The diameter and tensile strength of polyglycolic acid sutures can be controlled during manufacturing. This makes it easier to produce uniform strands of greater tensile strength than with the production of surgical gut.

Polyglactin 910 (Vicryl) is a copolymer of lactide and glycolide coated with polyglactin 370 and calcium stearates. It is similar biologically and physically to polyglycolic acid sutures. Maximum reabsorption is reached within 90 days but adequate strength is maintained for up to 21 days. Its major uses are in tissue layer closure (fascia, muscle, tendon, subcutaneous fat and subcuticular skin). Polyglactin 910 coated is available either dyed violet or undyed (natural). The dye is used to enhance visibility in tissues. Dexon S, an uncoated second generation suture has finer filaments which provide a tighter, smoother braid for optimum handling as compared to the original Dexon. Dexon Plus was also introduced and has a smooth coating of poloxamer 188 providing easier handling and less tissue drag. In addition, they allow repositioning of a square knot.

MONOFILAMENT NYLON (DERMALON, ETHILON)

Monofilament nylon is a nonabsorbable synthetic suture material. It is popular because of its minimal tissue reactivity. It has a very low tissue drag and high tensile strength due to its monofilament construction. This smoothness also allows for ease of removal from tissues. However extra ties are necessary to prevent slippage. Nurolon and Surgilon, synthetic braided nylon fibers allow excellent knot security but offer no great advantage over monofilament nylon.

POLYPROPYLENE

Monofilament polypropylene (Surgilene, Prolene) is a linear hydrocarbon fiber processed as a monofilament suture. As a synthetic nonabsorbable suture, it is extremely smooth, totally unaffected by tissue fluids and retains its tensile strength indefinitely. Due to these properties, polypropylene is indicated in the closing of contaminated wounds. However, due to the material's memory and smooth surface, it too has a propensity to allow slippage of the knot.

POLYESTER

Polyester sutures are made from a nonabsorbable synthetic material which is retained for an indefinite period of time. Having the greatest tensile strength of any suture allows for its use in ligament and capsule repair, and in peripheral vascular procedures requiring tissue to graft suturing.

Untreated polyester fibers (polyethylene terephthalate- Mersilene, Dacron) can be closely braided into multifilament strands to yield sutures which are stronger than natural fibers. This combination affords minimal tissue reaction while providing excellent knot security. Ticron is a silicone-treated braided polyester suture which has high tensile strength and smooth, supple handling. Ethibond is braided polyester coated with polybutilate which acts as a suture lubricant to allow for the smooth passage of suture through tissues. Polydek and Ethiflex are polyester sutures treated with varying degrees of Teflon coating to ease the suture through tissues without causing insult. Ethibond has been used successfully in

podiatric surgery due to its inert properties and ability to minimize tissue reaction.

POLYDIOXANONE

PDS (polydioxanone) is a monifilament synthetic absorbable suture prepared from polyester poly (p-dioxanone). It was the first absorbable suture to provide a great degree of flexibility while offering at least 6 weeks of wound support. After implantation for approximately 2 weeks, 70% of its original strength remains. At four weeks, approximately 50% of its original strength remains. PDS has been used successfully in all types of forefoot surgery most notably Austin bunion correction and digital surgery.

STAINLESS STEEL

Stainless steel has the highest tensile strength of any nonabsorbable suture material. The knot security with monofilament stainless steel is fair, requiring special tying techniques to prevent slippage. Usually the ends are twisted together rather than tied to secure tissue approximation. Knot security is better with multifilament stainless steel, which can be tied with the same techniques as braided nonabsorbable sutures. Flexon is a twisted multi-strand of a ferrous alloy. It is used for tendon and ligament and bone repair, and in cases of contaminated wounds. The ROTO-Grip needle which can be attached to certain monofilament sutures, is swaged to the suture so as to allow the needle to turn 360 degrees on the suture.

STITCH TECHNIQUES

The two major types of surgical stitches used by surgeons to close wounds are interrupted stitches and continuous stitches. Interrupted over-and-over, continuous (or running) over-and-over, and subcuticular stitches are shown (Fig. 1A, B, C)

In the interrupted stitch, each stitch is separate and tied independently of the other stitches. These stitches continue to offer support even if one breaks. Continuous stitching involves making more than one stitch with a single suture strand before the knot is tied. This stitch may be done more rapidly than interrupted stitching since there are fewer knots to tie. Both interrupted and continuous stitches can be sewn as mattress stitches. In a mattress stitch the needle and suture is passed through the tissue twice before tying the stitch. These stitches are used to alter the angle at which the suture pulls on the wound edges. (Fig. 2)

Interrupted mattress stitches include the vertical mattress which inverts the wound edges, the horizontal mattress, which everts the wound edges, and the figure-of-eight (Fig. 3). Finally, continuous mattress stitches include continuous inverting, continuous everting and the purse string continuous stitch (Fig. 4).

Retention stitches are used to reinforce the primary suture line, thus a heavy strong suture material is used. (Fig. 5) Retention suture bolsters or bumpers can be used to prevent the heavy suture materials from cutting into the skin.

Surgical Knots

Surgical knots are essential for the success of a surgical procedure. Certain principles are generally followed including the use of small knots to minimize foreign body reactions and the avoidance of tying sutures too tightly which can lead to tissue strangulation and necrosis. In tightening the sutures, one must also make an allowance for postoperative swelling and edema.

The most frequently used surgical knot is the square knot (Fig. 6). A variation of the square knot is the Surgeon's knot, where an extra throw is made to prevent slippage (Fig. 7). The combination knot is useful when the knot must be adjusted or when access is limited or difficult (Fig. 8).

Ligatures

A ligature is a strand of suture material used to tie off incised or tortuous blood vessels, thereby establishing hemostasis. Metal ligating clips are sometimes used instead of sutures to ligate blood vessels. Ligatures are selected for use according to the location and size of the blood vessels involved. The objective is to select the finest size of material which will effectively prevent blood flow. In general, this means that the deeper the blood vessel within the body, the larger the blood vessel within the body, and the larger the diameter of the ligature necessary to gain

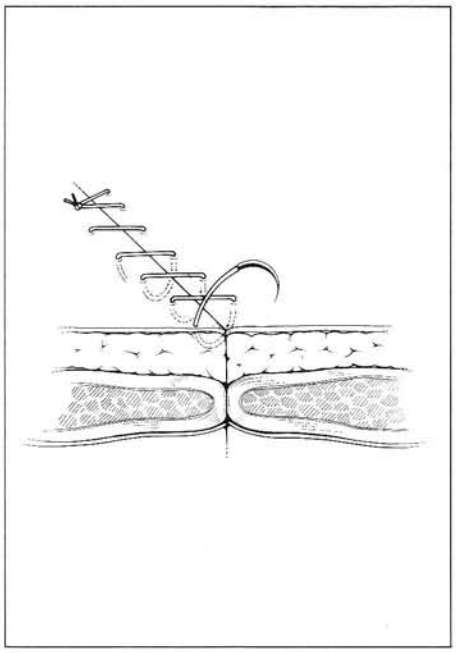

Fig. 1A. Running Stitch

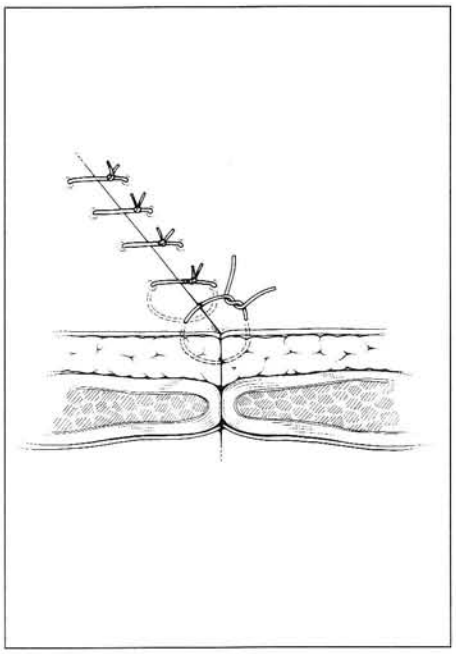

Fig. 1B. Interrupted Stitch (simple)

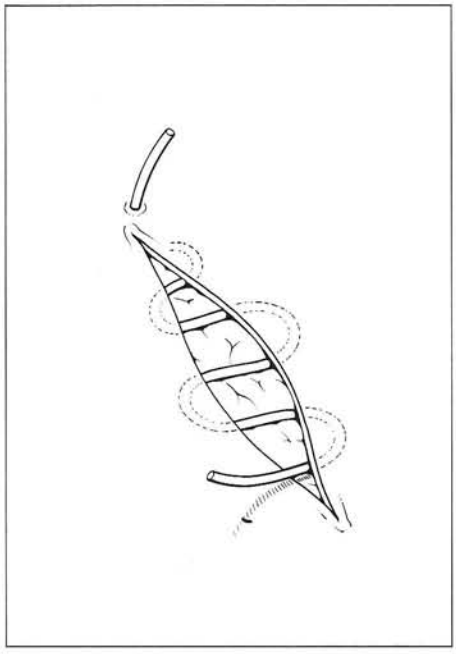

Fig. 1C. Subcuticular Stitch

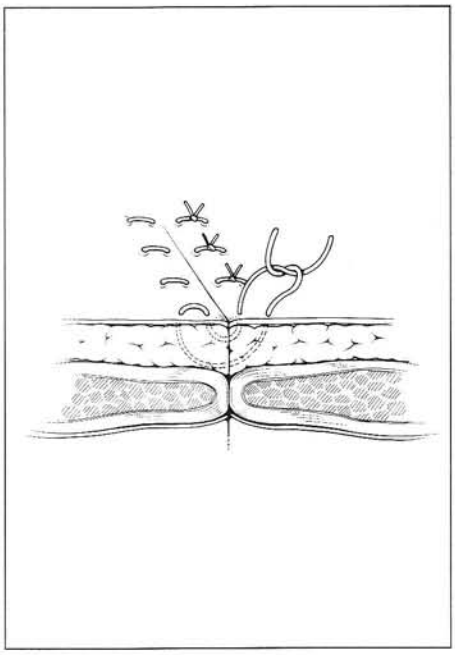

Fig. 2. Interrupted Vertical Mattress Stitch

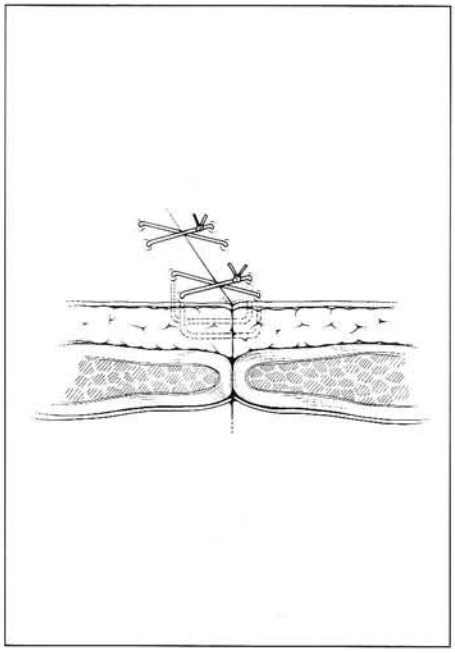

Fig. 3. Figure-of-Eight

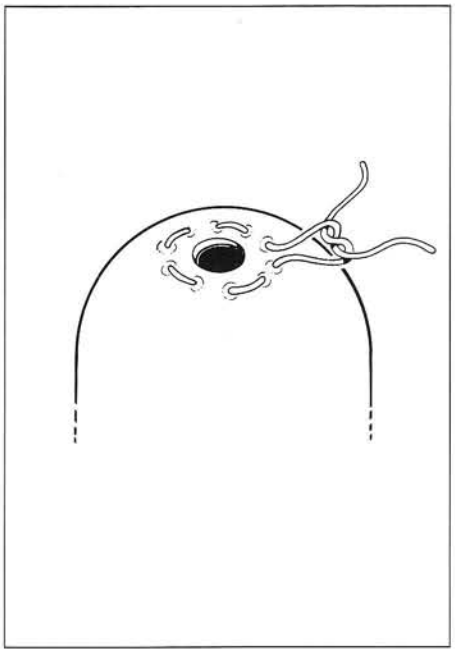

Fig. 4. Purse String

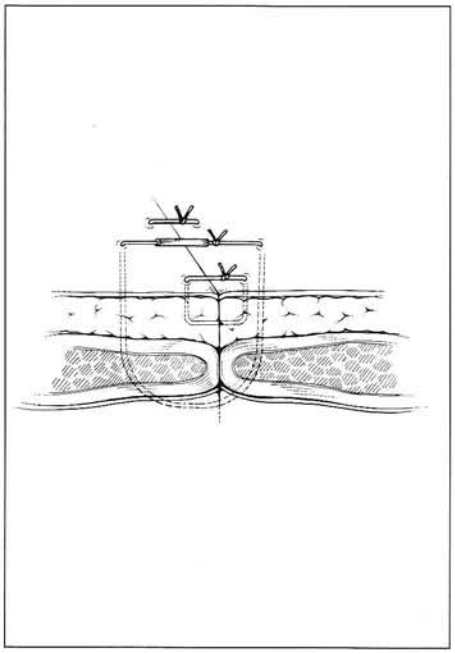

Fig. 5. Retention Stitches

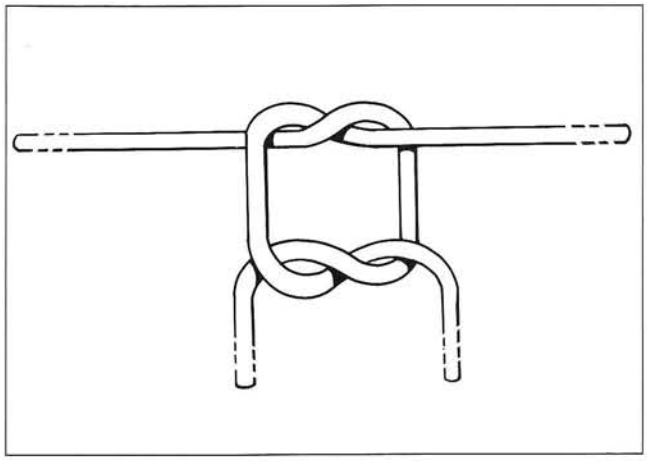

Fig. 6. Square Knot

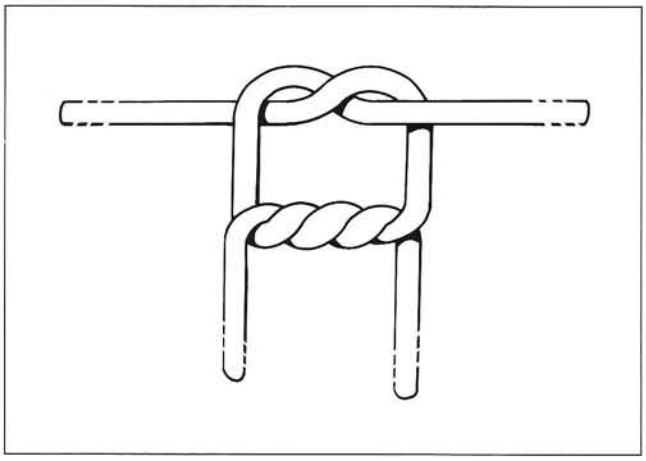

Fig. 7. Surgeons Knot

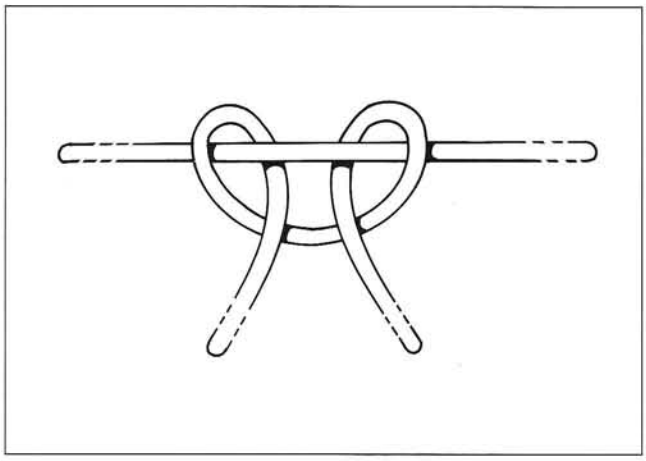

Fig. 8. Combination Knot

hemostasis. Ligatures are available in one of two ways; in pre-cut lengths of 18", 24", 30" and 54", or as a ligature reel. In general, the larger the diameter, the longer the pre-cut length.

NEEDLES

Sutures are attached to needles in two basic ways. One way is for the suture to be attached to an eyeless needle by the drilled-end or flange method. The second way is to thread a suture through a hole or eye located in the shaft of the needle.

Eyeless needles or swaged needles have the suture attached within the metal of the needle so the diameter of the needle is not significantly greater than the diameter of the suture. This minimizes trauma to the tissue and leakage at anastomotic sites. The term swaging refers to the process of attaching suture strands to eyeless needles.

Eyed needles are available in three types; round, square and split-eye (or French eye). Surgical needles have distinguishing characteristics which include the curvature (straight or curve shaft), needle length, wire diameter, and the type of point. The common needle shapes include; straight, 3/8 circle, 1/2 circle, and 5/8 circle. Straight needles are primarily used for skin closure or tendon repair.

Curved needles are described based on arc length, chord length, and including angle. The arc length is the length of the needle as measured along its arc, or curve. The chord length refers to the straight line distance measured between the point and the end of a curved needle. Included angle is the number of degrees included in the angle.

Needle points may be either tapered, cutting, or blunt. Tapered needle points have a round shaft with a flattened portion to hold the needle in the needle holder. Taper point needles are used in tissue that offers little resistance to the needle, such as fascia, subcutaneous tissue, or vascular tissue. As a general rule, this type of needle is used for softer red tissue with ample blood supply, whereas cutting edge needles are used for tougher white tissue, such as tendon and ligaments.

Cutting edge needles are used in tissues such as skin, periosteum and bone. This type of needle is available in many different configurations. The most commonly used cutting edge needle is the reverse cutting. The reverse cutting appears in a cross section as an upended triangle. This needle will not tend to cut up through the tissue because the sharp edge is on the outer curvature. This makes it less likely for the suture to tear through the tissue.

Conventional or regular cutting needles are used in tough tissues, such as tendon and skin, where a taper point needle cannot easily penetrate. Other variations of cutting edge needles include the spatula, penetrating point, diamond point, and lancet needles. The spatula point is diamond shaped with the cutting edges in the lateral plane only and widens out to allow easy passage of the shaft through the tissue. The spatula is generally used in eye surgery for repair of muscle and detached retina, and may be used for eyelid plastic surgery.

A diamond taper (diamond point or diamond tip) has a side cutting point on a tapered shaft. The tip is smaller than the shaft to prevent excessive cutting. This type of needle point is used for extra penetration. For example, the diamond taper is generally used on ligamentous, tendinous, or fibrous tissue. Its greatest use is in thoracic, orthopedic, and revisional surgery.

The penetrating point is similar to the diamond point, however the cutting edge is on the tip only, as compared to the diamond point whose cutting edge extends further back on the needle. The greatest demand for the penetrating point is in vascular surgery procedures.

The lancet needle primarily employed in opthalmic surgery is a spatula with a cutting lancet point. It is a reverse cutting needle with the bottom cut off, and an inverted lancet is a lancet turned over.

A blunt point needle has a tapered body with a rounded point and no cutting edge. It is used primarily for organ repair where the blunt tip will help prevent the needle from piercing blood vessels. It is also used in parasternal closure.

Precision point cutting or hand honed reverse cutting needles are used typically for plastic or cuticular procedures. The SBE (slim blade edge) needle is recommended for skin closure because it is atraumatic, and a hole can not be visualized.

Current research and development in the needle market is refining a needle made of a more durable alloy to prevent breakage while maintaining a precision micro point and body for skin closure. See Table 2 for needle abbreviations and descriptions.

SUMMARY

Suture manufacturers are currently developing new materials or modifying current ones, so as to enhance strength while maintaining tissue reaction. Future needles will need to be more durable and less traumatic to tissues as specific needs arise.

With the proper needle and suture selection wound healing can be enhanced resulting in minimal scarring and optimal strength.

TABLE 2

ABBREVIATIONS FOR COMMONLY USED ASTRALAC NEEDLES

CP	Cutting point
CPS	Conventional plastic surgery
FS	For skin
FSL	For skin larger
FSLX	For skin large extra
P	Plastic surgery
PC	Precision cosmetic
PS	Plastic surgery
SH	Small half
V	Taper cut needle

ABBREVIATIONS OF SWAGED ATRAUMATIC NEEDLES

NEEDLE CODE:	
S	Straight needle
1/2 circle	No additional letter
3/8 circle	E
1/4 circle	O
5/8 circle	Repeated letter (TT)
C	Reverse cutting
DT or DG	Diamond point
PR	Hand honed reverse cutting
SC or MC	Conventional cutting
T	Taper point

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