Surgical instruments, sutures and suturing techniques

The history of suturing

Anthropological studies suggest that prehistoric man used various techniques to close skin wounds (Ellis, 2001). The jaws of termites or beetles were used to bite across wounds and hold skin edges together in India and South America, and in East Africa acacia thorns were stuck along the two wound edges and then plaited together (Ellis, 2001). Suture materials used included horsehair, fibres from tree bark, cotton and, in ancient Rome, human hair and catgut (made from sheep's intestine) (Burnand and Young, 1998), which was used until recently in the UK. The sutures used in modern surgical practice are almost exclusively synthetic materials.

Surgical instruments

The instruments required for suturing using a curved needle include a needle holder, forceps and scissors. The needle holder is used to place and push the needle through the skin and the forceps to hold the skin edges everted as the needle is placed and also to pick up the needle. Some surgeons prefer to use a skin hook to evert the skin edges (McGregor and McGregor, 2000).

Many different needle holders are available and choice is usually determined by personal preference. Considerations when choosing the appropriate needle holder include the clamping moment of ratchet needle holders, i.e. the magnitude of force required to overcome the ratchet mechanism, and the design of the needle holder jaw. The clamping moment of ratchet needle holders should not exceed the yield moment of the needle chosen, otherwise irreversible deformation of the curved needle will occur in the flat jaws of the needle holder, resulting in an unpredictable trajectory of the needle through the tissue being sutured (Edlich et al, 1990; Chen et al, 1991). This problem can be overcome by careful use of a needle holder with no ratchet lock.

Textured tungsten carbide needle holder jaw inserts provide superior needle grip to smooth jaw inserts and have less potential to damage suture material and needle structure than jaw inserts with teeth (Edlich et al, 1993). Needle holders with rounded jaw edges are less likely to damage suture material than the sharp outer edges of flat-jawed needle holders (Edlich et al, 1993). When performing microsurgery very fine instruments are required. Jeweller's or watchmaker's forceps are used along with spring-handled needle holders and scissors (Shurey and Green, 2004). Microsurgical needle holders are held like a pen or pencil (McGregor and McGregor, 2000) and may have flat or round grips, and tips that may be straight, curved or angled (Shurey and Green, 2004).

Needles

Modern surgical needles come in various shapes and sizes, have different types of tips and are attached or swaged to the suture material. The suture material is placed into a hole drilled in the end of the needle and crimped in place meaning that only a single strand of suture material is pulled through the tissue (Edlich et al, 1993). Hand-held straight needles are now less popular than instrument-held curved needles as they carry a greater risk of needle-stick injury. Curved needles range from a quarter to five eighths of a circle with larger arcs used in more confined operative sites (Trier, 1979). J-shaped needles may be used in deep cavities. Compound curved needles have a straight tip followed by a curved section. The straight tip facilitates tissue penetration and the curved section allows easy passage through the tissue, while the overall design enhances resistance to bending (Edlich et al, 1993).

Needle tips may be cutting, reverse cutting, round bodied or tapered. Cutting needles are used in tissues that are difficult to penetrate, including skin, tendon and ligament, and care must be taken when using them to avoid unwanted tissue damage caused by the cutting tip (Trier, 1979). The reverse cutting needle, in which the cutting surface is along the convex side of the needle rather than the concave side, was designed in an attempt to reduce unwanted tissue damage (Trier, 1979). Round-bodied needles are used for gastrointestinal and vascular anastomoses and in other tissues where tearing or additional cutting must be avoided (Trier, 1979). The suture material completely fills the hole left by the needle thus minimizing leakage after anastomoses. Tapered needles have the benefit of a cutting tip on a round-bodied needle shaft (Trier, 1979).

Sutures

Properties of suture material

The choice of the appropriate suture for a particular wound is influenced by properties of the suture such as handling, knot security and tissue reactivity. These properties are influenced, in turn, by the type and size of suture material (see below). Handling and knot security are affected by the memory, elasticity and tensile strength of the suture material.

The tendency of a suture to return to its original shape or position is described as memory (Moy et al, 1991a). Higher memory makes suture handling and knot tying more difficult and increases the likelihood of knots becoming untied (Moy et al, 1991a). Elasticity is a measure of the ability of suture material to return to its original form after stretching and is a desirable feature as it allows the maintenance of wound edge apposition with the resolution of tissue oedema (Moy et al, 1991a). Tensile strength represents the force per unit of cross-sectional area required to break the suture material (Moy et al, 1991a). The advantage of using a suture with a higher tensile strength is

Mr Jim Bush *is Senior Clinical Research Fellow, Renovo plc, The Incubator Building, Manchester and* **Mr Ardeshir Bayat** *is Clinician Scientist in Plastic and Reconstructive Surgery Research, Manchester Interdisciplinary Biocentre, Manchester M1 7ND*

Correspondence to: Mr A Bayat

that a finer suture can be used, meaning that less foreign material is present at the wound site (Herrman, 1971).

Knot strength is related to the coefficient of friction of the suture material and represents the force required to cause a knot to slip (Moy et al, 1991a). Higher knot security means that fewer throws are required on the knot, again reducing the amount of foreign material present (Herrman, 1971).

Tissue reactivity or inflammation in response to suture material is undesirable as it may lead to a worse scar. Although different suture materials may elicit varying tissue responses, patient and surgeon factors may be more important in predicting tissue reactivity than choice of suture material in single-layered skin closures (Gabrielli et al, 2001).

Suture materials

Both natural and synthetic fibres are used in the manufacture of sutures and these fibres may be absorbable or non-absorbable and monofilament or multifilament. Some commonly used sutures are listed in *Table 1*.

Natural *vs* synthetic

Natural fibres used include catgut and silk. Synthetic sutures include those made from polymers such as nylon (polyamide) or polyester and also metallic (stainless steel) wires. Natural fibres produce a greater tissue reaction than synthetic fibres (Moy et al, 1991a) but have a lower tensile strength than synthetic polymers which, in turn, are weaker than metallic wires (Herrman, 1971).

Absorbable *vs* non-absorbable

Absorbable sutures are degraded by either proteolysis (natural fibres) or hydrolysis (synthetic sutures) so that they lose tensile strength. Despite this loss of tensile strength, suture material remains at the wound site (Moy et al, 1991a).

Similar cosmetic results have been obtained using absorbable and non-absorbable sutures (Parell and Becker, 2003), although the inflammatory response is greater with absorbable sutures (Setzen and Williams, 1997). Absorbable sutures have the advantage that they do not have to be removed which is particularly useful in children.

Monofilament *vs* multifilament

Single stranded or monofilament sutures tend to have more memory and are more difficult to handle than multifilament sutures in which the strands are braided or twisted together. Multifilament sutures evoke a more pronounced inflammatory response than monofilament sutures (Setzen and Williams, 1997).

Suture size

The United States pharmacopoeia provides a standard classification of suture diameter (Moy et al, 1991a). Sutures were initially sized as 3, 2 or 0 with decreasing diameters. With the manufacture of finer sutures further 0s were added. The number of 0s is represented by a digit followed by 0. i.e. 4/0 (0000) is smaller than 2/0 (00). The finest suture today is 12/0. Sutures smaller than 6/0 are used for ophthalmic or microsurgery.

Suturing techniques

The objective of wound suturing is to maintain wound edge apposition and eversion during wound healing (Moy et al, 1991b; Adams et al, 2003) with the addi-

Table 1. Commonly used suture materials and information on length of effective wound support

Trade name	Generic name	Natural/ synthetic	Absorbable/ non-absorbable	Monofilament/ multifilament	Length of wound support
Plain Gut	Gut fibre	Natural	Absorbable	Multi	7–10 days
Mild Chromic Gut	Gut fibre with chromium salt	Natural	Absorbable	Multi	10–14 days
Chromic Gut	Gut fibre with chromium salt	Natural	Absorbable	Multi	10–14 days
Vicryl Rapide	Polyglactin 910	Synthetic	Absorbable	Multi	10 days
Monocryl	Poliglecaprone	Synthetic	Absorbable	Mono	20 days
Vicryl	Polyglactin 910	Synthetic	Absorbable	Multi	30 days
Vicryl Plus	Polyglactin 910 (Triclosan coated)	Synthetic	Absorbable	Multi	30 days
Maxon	Polyglyconate	Synthetic	Absorbable	Mono	6 weeks
PDS	Polydioxanone	Synthetic	Absorbable	Mono	60 days
Mersilk	Silk	Natural	Non-absorbable	Multi	3 months
Ethilon/Dermalon	Polyamide	Synthetic	Non-absorbable	Mono	Prolonged
Nurolon/Surgilon	Polyamide	Synthetic	Non-absorbable	Multi	Prolonged
Pronova	Poly (Hexafluoropropylene-VDF)	Synthetic	Non-absorbable	Mono	Prolonged
Mersilene	Polyester	Synthetic	Non-absorbable	Mono/multi	Prolonged/permanent
Ethibond	Polyester (Polybutylate coated)	Synthetic	Non-absorbable	Multi	Permanent
Prolene/Surgipro	Polypropylene	Synthetic	Non-absorbable	Mono	Permanent
Novafil	Polybutester	Synthetic	Non-absorbable	Mono	Permanent
Stainless steel	Stainless steel	Synthetic	Non-absorbable	Mono/multi	Permanent

tional aim of producing a scar that is both functionally and cosmetically acceptable (Adams et al, 2003).

Sutures may be continuous and run along the entire length of a wound or interrupted, where each separate suture is secured with a knot (Moy et al, 1991b; Adams et al, 2003). Continuous sutures are generally quicker to insert and distribute tension evenly along the entire length of the wound (Moy et al, 1991b; Adams et al, 2003), however, if complications such as infection occur the entire suture has to be removed, whereas with interrupted sutures one or two may be removed to release a localized collection (Adams et al, 2003). Any interrupted suture can be converted into a continuous suture by starting the next suture without knotting the previous one (Adams et al, 2003). When closing deep wounds each layer is closed successively to restore anatomical configuration of the tissues (Adams et al, 2003).

Simple sutures

A simple suture takes a bite of epidermis and dermis on each side of the wound and is tied to one side (*Figure 1*). Wound edge eversion can be achieved by taking a larger bite of the deeper tissue than the superficial tissue (Adams et al, 2003). If tied too tightly or not removed early enough these sutures will leave unsightly stitch marks along the edges of the scar (Moy et al, 1991b; Adams et al, 2003). Simple sutures have many applications including the closure of skin wounds, closure of deeper layers such as fascia and subcutaneous fat, vascular and gastrointestinal anastomoses and nerve repairs.

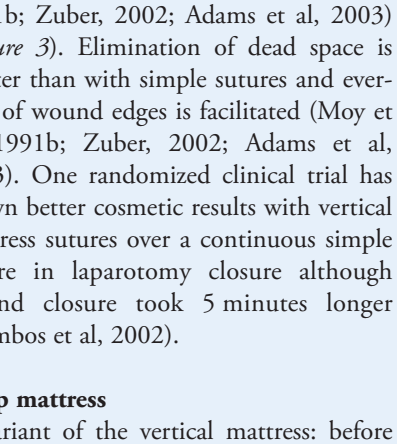


Figure 2. Cross-stitch.

Cross-stitch

A continuation of the simple interrupted suture in which a second simple interrupted suture is placed next to the first without cutting the suture, the end of the second suture is tied across to the start of the first creating a X shape (Barbar, 1997; Ahmed, 2002) (*Figure 2*). This is useful for closing small skin defects (Adams et al, 2003) and also for repair of extensor tendons (Ahmed, 2002).

Mattress sutures

Vertical mattress

This has also been termed the far-far, near-near suture because of the way in which the tissue bites are taken (Zuber, 2002; Adams et al, 2003). A slightly wider bite is placed than with the simple suture (far-far), the needle is then reversed and, re-entering on the same side as the suture just left the skin, a second smaller, more superficial bite is taken in line with the original bite (near-near), the suture is tied on the side that it originally pierced the skin (Moy et al, 1991b; Zuber, 2002; Adams et al, 2003) (*Figure 3*). Elimination of dead space is greater than with simple sutures and eversion of wound edges is facilitated (Moy et al, 1991b; Zuber, 2002; Adams et al, 2003). One randomized clinical trial has shown better cosmetic results with vertical mattress sutures over a continuous simple suture in laparotomy closure although wound closure took 5 minutes longer (Trimbos et al, 2002).

Loop mattress

A variant of the vertical mattress: before tying, the leading end of the suture is taken back across the wound line and passed through the loop of external suture on the opposite side (Gault et al, 1987). This creates a pulley which reduces the force required to achieve wound closure, thus reducing the risk of cheese wiring of the external loop through the skin.

Space-obliterating suture

Another modification of the vertical mattress suture. During placement of the initial far-far suture bite, a further looped bite is taken within the dermis (Arnold, 1997). The suture is then completed as a normal vertical mattress. This suture provides additional closure of dead space for use in deep wounds.

Horizontal mattress

Place a 'simple interrupted suture' then reverse the needle and place a second suture bite a few millimetres lateral to the first so that the needle emerges on the side where it first pierced the skin and tie the suture (Zuber, 2002; Adams et al, 2003) (*Figure 4*). This suture is more haemostatic

Figure 1. Simple sutures.

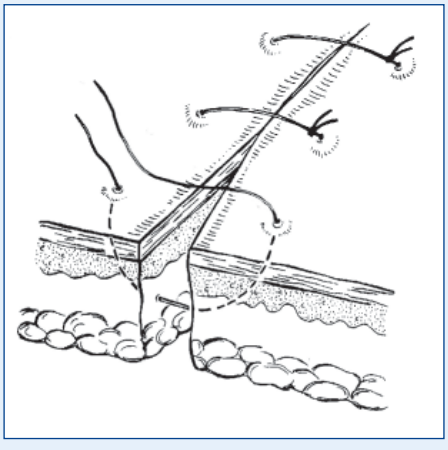


Figure 3. Vertical mattress sutures.

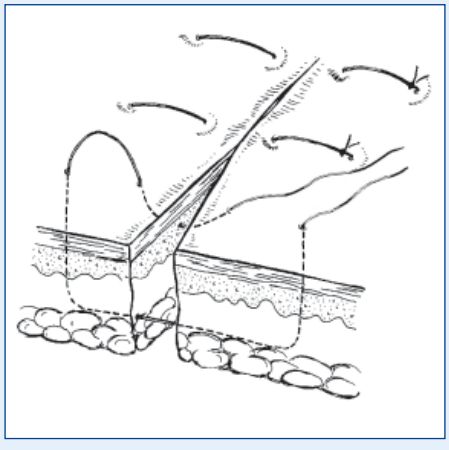
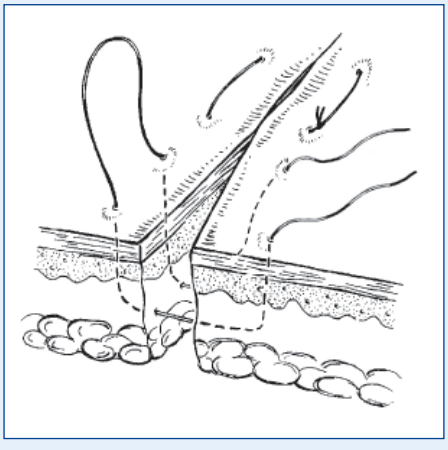


Figure 4. Horizontal mattress sutures.



than the simple suture, promotes wound edge eversion and is useful for closing defects under greater tension (Zuber, 2002; Adams et al, 2003).

Corner stitch or half-buried mattress

In areas where the potentially strangulating external loop of the horizontal mattress should be avoided, such as when closing local flaps or Y-shaped wounds, this variation of the horizontal mattress can be used (Moy et al, 1991b; Zuber, 2002; Adams et al, 2003). The stitch is started by piercing the skin on the opposite side of the wound to the corner or flap, then taking a horizontal, dermal bite of the corner or flap without piercing the epidermis, and then emerging and tying on the same side of the wound that the suture started (Moy et al, 1991b; Zuber, 2002; Adams et al, 2003) (*Figures 5a* and *b*).

Subcuticular suture

A running suture that is placed entirely within the dermis (*Figure 6*). The epidermis is only pierced where the suture enters and leaves the skin (Moy et al, 1991b; Adams et al, 2003). As there is no risk of leaving stitch marks, the suture can be left in place for prolonged periods, if necessary. When closing deep wounds more than one layer of subcuticular sutures can be placed.

Purse-string

A running subcuticular 'purse-string' placed around a circular defect can be used to close small circular wounds (Tremolada et al, 1997; Mulliken et al, 2002) or to reduce the size of larger circular wounds (James, 1996) for subsequent closure with a skin graft.

Buried sutures

Buried absorbable sutures with deeply placed knots are often required in deep wounds to close dead space and reduce tension on the epidermal closure (Moy et al, 1991b; Adams et al, 2003). Simple (Adams et al, 2003), vertical mattress or butterfly (Moy et al, 1991b; Adams et al, 2003) and horizontal mattress sutures have all been described (Alam and Goldberg, 2004). BJHM

Conflict of interest: none.

Adams B, Anwar J, Wrone DA, Alam M (2003) Techniques for cutaneous sutured closures: variants and indications. *Semin Cutan Med Surg* **22**(4): 306–16

Ahmed OA (2002) The versatile cross stitch. *Br J Plast Surg* **55:** 701–2

Figure 5. a. Corner stitch or (b) half buried mattress.

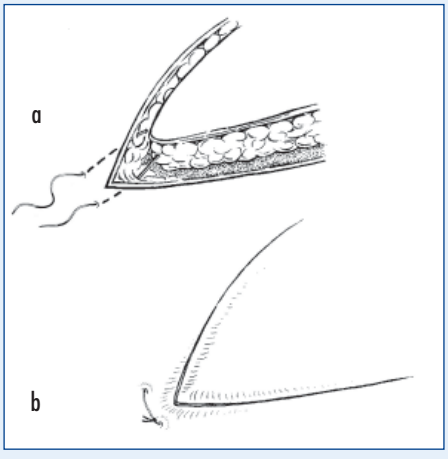
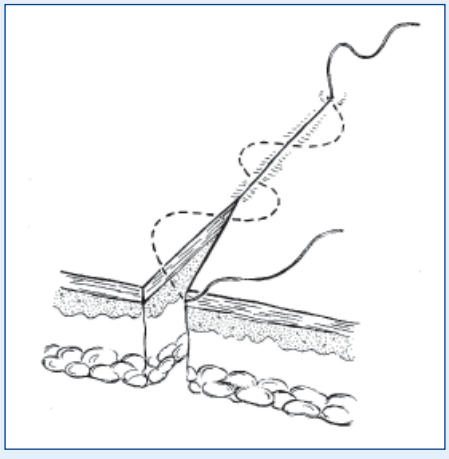


Figure 6. Subcuticular suture.



KEY POINTS

- Man has been closing skin wounds since prehistoric times.
- Modern suture materials vary in terms of handling, knot security and tissue reactivity.
- Suture materials may be natural or synthetic, absorbable or non-absorbable and monofilament or multifilament.
- Various suturing techniques exist including simple sutures, mattress sutures and subcuticular sutures.
- The objective of wound suturing is to maintain wound edge apposition and eversion during wound healing.

Alam M, Goldberg LH (2004) Utility of fully buried horizontal mattress sutures. *J Am Acad Dermatol* **50:** 73–6

Arnold PG (1997) Space obliterating skin suture. *Plast Reconstr Surg* **100**(6): 1506–8

Barbar AZ (1997) Interrupted skin suturing with "cross stitch". *Plast Reconstr Surg* **100:** 1620–1

Burnand KG, Young AE, eds (1998) *The new Aird's companion in surgical studies.* 2nd edn. Churchill Linvingstone, London

Chen NC, Towler MA, Moody FP, McGregor W, Himel HN, Thacker JG, Edlich RF (1991) Mechanical performance of surgical needle holders. *J Emerg Med* **9:** 5–13

Edlich RF, Towler MA, Rodeheaver GT, Becker DG, Lombardi SA, Thacker JG (1990) Scientific basis for selecting surgical needle holders for wound closure. *Clin Plast Surg* **17**(3): 583–602

Edlich RF, Thacker JG, McGregor W, Rodeheaver GT (1993) Past, present, and future for surgical needles and needle holders. *Am J Surg* **166:** 522–32

Ellis H (2001) *A history of surgery.* 1st edn. Greenwich Medical Media Ltd, London

Gabrielli F, Potenza C, Puddu P, Sera F, Masini C, Abeni D (2001) Suture materials and other factors associated with tissue reactivity, infection, and wound dehiscence among plastic surgery outpatients. *Plast Reconstr Surg* **107**(1): 38–45

Gault DT, Brain A, Sommerlad BC, Ferguson DJP. (1987) Loop mattress suture. *Br J Surg* **74:** 820–1

Herrman JB (1971) Tensile strength and knot security of surgical suture materials. *Am Surg* **37**(4): 209–17

James Y (1996) Versatility of the subcuticular purse-string suture in wound closure. *Plast Reconstr Surg* **98**(7): 1302–5

McGregor AD, McGregor IA (2000) *Fundamental techniques of Plastic Surgery and their surgical applications.* 10th edn. Churchill Linvingstone, London

Moy RL, Lee A, Zalka A (1991a) Commonly used suture materials in skin surgery. *Am Fam Phys* **44**(6): 2123–7

Moy RL, Lee A, Zalka A (1991b) Commonly used suturing techniques in skin surgery. *Am Fam Phys* **44:** 1625–34

Mulliken JB, Rogers GF, Marler JJ (2002) Circular excision of haemangioma and purse-string closure: the smallest possible scar. *Plast Reconstr Surg* **109**(5): 1544–54

Parell JP, Becker GD (2003) Comparison of absorbable with nonabsorbable sutures in closure of facial skin wounds. *Arch Facial Plast Surg* **5:** 488–90

Setzen S, Williams EF (1997) Tissue response to suture materials implanted subcutaneously in a rabbit model. *Plast Reconstr Surg* **100**(7): 1788–95

Shurey S, Green C (2004) *Basic microsurgical techniques – a laboratory manual.* Surgical research dept. NPIMR, Northwick Park Hospital, Harrow, Middlesex, UK

Tremolada C, Blandini D, Beretta M, Mascetti M (1997) The "Round Block" purse-string suture: a simple method to close skin defects with minimal scarring. *Plast Reconstr Surg* **100**(1): 126–31

Trier WC (1979) Considerations in the choice of surgical needles. *Surg Gynaecol Obstet* **149**(1): 84–94

Trimbos JB, Mouw R, Ranke G, Trimbos KB, Zwinderman K (2002) The Donati stitch revisited: favourable cosmetic results in a randomized clinical trial. *J Surg Res* **107:** 131–4

Zuber T (2002) The mattress sutures: vertical, horizontal, and corner stitch. *Am Fam Phys* **66**(12): 2231–6