RECENT ADVANCES IN 12

SURGERY

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EDITED BY
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Preface

The middle eighties mark a watershed for general surgery, which is undergoing a change from traditional techniques and practices to incorporating and adjusting to the scientific development that has been taking place over the last twenty years. The surgeon has accepted the challenge and his interests have adapted to modern technology. Lord Lister introduced the concept of the sterile suture, and until recently suture principles had changed little, but now techniques are developing which may change our practice: why do surgeons still tie knots? The concept of no scar surgery has always been a Utopian aim, yet it is nearer than many dare believe. Cutting for stone may well be relegated to the history of surgery if the descriptions of stone removal in Chapters 6 and 13 are effective in the long term. Even pus may no longer be the sole prerogative of the surgeon for the interventional radiologist, a new specialist encroaching on the surgeon, is able to aspirate pus within body cavities with results as good, if not better, than incision and drainage.

New techniques will enable the surgeon to be more accurate in his preoperative diagnosis, and as a result of careful analysis, based on research, define the role of surgery with greater benefit to the patient. Those difficult problems of the management of the thyroid nodule, bleeding varices, oesophageal reflux and anal incontinence have become areas of interest with consequent clarity in thought and resultant benefit to the sufferer. Even fracture management has now understandable principles for the generalist with an approach very different from those enumerated in early editions of this series. Vascular surgery continues to progress, but often the patient does not receive these benefits: the results of specialisation have been poorly utilised, as exemplified by the lack of knowledge related to dissecting aneurysm — a salvable condition in many instances, yet one which is rarely treated.

Cancer remains stubbornly elusive to technology, and here the surgeon is continuing to look at early detection, with or without the aid of marker substances, or just trying to determine what he is achieving: how little interest and care has been taken in the surgical management of cancer of the stomach recently! To define a problem is not an end in itself, but in the practical realities of the present decade, no surgeon will be able to neglect a comprehensive audit of his work. Without shame, therefore, the last chapter examines the computer in surgery: an uncomfortable companion or a future workhorse?

In compiling this twelfth volume, I have been helped by many people, all of whom I wish to thank, particularly the staff of Churchill Livingstone.

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INTRODUCTION

Sutures have been used for as far back as records go both to hold wounds together and to arrest haemorrhage. The thread and the instruments for its application were made from any convenient available materials, so that the very earliest eyed needles were fashioned from bone; threads were made of flax, hemp, bark fibres and hair (the senior author can still remember when a hair from the theatre sister's head was judged the best material for nerve repair). Today, closure methods which do not use conventional suture materials are available but even these are by no means new. Primitive men in South America used large black ants to bite the edges of a wound together, their powerful jaws acting in a similar manner to metal clips. The ant's body was then twisted off, leaving the head in place. The Susutura, an early Indian surgical text, describes closure of the intestines after enterotomy for obstruction using the same technique. Similarly ancient Egyptian papyri refer to the use of linen strips, coated with an adhesive mixture of flour and honey for skin closure.

Catgut, made from the submucosa of the intestines of herbivores, constitutes nearly one half of currently used sutures today. The first textual reference to it comes from Galen (circa A.D. 150) who makes it clear that it had been employed from centuries before. He also recommended the use of silk which was available 'especially in large cities where there are many wealthy women'. Today we have a greater choice of materials but until quite recently all had been developed for other purposes (catgut for example was available to the ancients because of its use to string musical instruments) and the surgeon's choice was largely the consequence of empirical judgements on ease of handling, strength, durability and incidence of infection. Formal research into suture characteristics is relatively new and the planned development of new materials, which we will discuss at the end of this chapter, even more recent.

It was not until the 18th century that the fact that catgut is absorbed (the better term might be digested) by the body was recognised. Philip Syng Physick (1768–1837), an American who had trained in Edinburgh before coming to London to study under John Hunter and who went on to become the first Professor of Surgery at the University of Pennsylvania, experimented with the use of adhesive strips made of leather for sutureless skin closure and noticed that these disintegrated after contact with fluid discharged from the wound. It occurred to him that ligatures that would eventually dissolve in the body would be of considerable benefit and he subsequently tried parchment, kid, varnished leather and catgut. His experiments mark an historic point for no one had previously considered the possibility of an absorbable suture which would perform its function and then disappear.

The next major step forward was made by Joseph Lister (1827–1912). He realised that infective agents might lurk in the interstices of sutures and that, if these could be killed, the suture might safely be left in the body. Up to this time the ends of ligatures used to control major vessels, say at the site of an amputation, had been left long to protrude out of the wound. After a varying period of time the tightly tied end of the vessel sloughed and allowed the ligature to be withdrawn; it is scarcely surprising that this method was prone to the complication of secondary haemorrhage and that it was associated with much discomfort. Lister's new sterile ligature would, he hoped, enable him to cut the ends short, leave them implanted and result in either absorption or encapsulation as he had noted happened to lead shot from a fowling piece. In 1867 he began to use catgut treated with an aqueous suspension of carbolic acid. He later improved the handling characteristics of the gut and delayed its absorption by chromicising — a technique of great antiquity learned from the tanning industry. Although sterilisation by iodine soon replaced carbolic acid, Lister's work constituted an important advance and generated a suture that has been extensively used ever since.

In recent decades new synthetic filaments such as nylon, polypropylene and polyester have become available, greatly widening the choice of material from which non-absorbable sutures can be made. Synthetic absorbables have also been developed specifically for use as surgical sutures with strength, handling characteristics and life in the tissues determined by design. Table 1.1 summarises the sutures currently available. There is now enough knowledge of the tissue response to sutures, of the relationship between sutures and sepsis and of their degradation in relation to the recovery of wound strength, to attempt a rational choice of material for specific uses. Technique always remains important — many, ourselves included, would say paramount — but to choose the best suture can make a contribution to outcome.

Lord Moynihan (1865–1936) considered that the four requirements for an ideal suture were that it should:

1. achieve its purpose — that is be sufficient to hold parts together against whatever stresses to which they were subject
2. disappear as soon as its work was accomplished
3. be free from the risks of infection
4. be non-irritant.

To some extent these criteria are mutually incompatible and every suture is a compromise. We believe that the 'ideal suture' is a theoretical concept — a surgical philosopher's stone — which cannot be achieved but serves as a stimulus for continued development.

In whatever circumstances a suture is to be used, there are some characteristics which are uniformly desirable. For example, it is an advantage if the material and the processes required to convert it into a suture are simple and cheap. A long shelf life, without stringent storage requirements, is helpful, particularly if the suture is one used for a special task which may only be undertaken infrequently. Absorbable sutures create more of a problem than nonabsorbables: they are chemically labile by design so as to be biodegradable, and a consequence of this is a tendency for the thread structure to break down with time. Deterioration is quicker the warmer the place of storage.

Packaging is also important, though as with many modern goods, it has tended to dominate the thinking of those who sell the sutures. The purposes of the package are to maintain sterility, allow easy identification, provide ease of opening and the

Table 1.1 Properties of common suture materials

Material	Nature	Type	Tissue response	Retention of tensile strength in vivo	Handleability	Potential advantages/ disadvantages
catgut	sheep submucosa	absorbable	inflammation more marked with plain catgut than chromic	plain — 2/3 lost in 5–6 days; chromic — 2/3 lost in 10–15 days	moderate	unpredictable loss of tensile strength; potentiation of sepsis though this is limited by absorption; variability of natural product
reconstituted collagen	sheep mucosa	absorbable	inflammation as with catgut	as for chromic catgut	moderate	as for catgut, but more reliable product
polyglycolic and polyglactin 910	synthetic polymer	absorbable	slight — absorbed with variable but muted inflammatory reaction	variable — 1/2 lost in 15 days	good	predictable loss of tensile strength; less potentiation of sepsis than catgut
polydioxanone	synthetic polymer	absorbable	slight	1/2 lost in 28 days	moderate	as above
linen	vegetable	non absorbable	moderate inflammation	1/3 — 1/2 strength lost in 3–6 months	very good	cheap; variable supply and performance
silk	silk worm	non absorbable	mild to moderate inflammation	1/2 strength lost in 2–12 months	very good	fairly cheap, cost likely to rise; variable supply
nylon	synthetic polyamide	non absorbable	minimal	2/3 strength retained up to 6 months	poor in monofilament, good in braid	knot slippage in monofilament
polypropylene	synthetic	non absorbable	minimal	as for nylon	superior to monofilament nylon	elastic; knot slippage; can fracture, e.g. artery
coated polyester	synthetic (PTFE coated braid)	non absorbable	minimal to moderate	as for nylon	good (braid plus monofilament coat)	knot slippage; coat fracture leads to increased inflammatory response
polytetrafluoroethylene	synthetic (expanded PTFE)	non absorbable	minimal	as for nylon	good	expanded microstructure allows incorporation into tissues; minimal sutureline bleeding (artery)
stainless steel	synthetic	non absorbable	virtually nil	monofilament shows fatigue fractures at 1 year	poor in monofilament, moderate in braided	inert; troublesome knots and wound pain

release of an untangled suture without injury from a needle or a splash in the eye from irritant preserving or stabilising solution (fortunately in modern practice only catgut and collagen require preservative to maintain pliability). Each suture package nowadays consists of an outer layer which when opened releases an inner package the surface and contents of which are also sterile. If the inner package is exposed during an operation but not opened, the suture can be used at a later date preferably after resterilisation of the cover. Some manufacturers offer a resterilisation service and sterilising fluids are also available. Such a system of recirculation is little used now in the United Kingdom but in parts of the world where resources are scarce, such facilities are important.

It is worthy of mention in this context that packaging and ease of dispensing do not alter the nature of the suture but they do add considerably to expense. In developing countries, in particular, it is vastly cheaper to buy nonabsorbable material in bulk (and at least in the case of nylon from piscatorial rather than surgical sources) and sterilise locally, accepting that there will be some decline in the properties of the suture if sterilisation is repeated too often. As long as the surgeon is cognisant of the decline in quality he can safely use the material without fear of disadvantaging his patients.

PROPERTIES OF SUTURES

Strength

It might seem obvious that a suture should be of predictable thickness and strength but for half of the sutures currently used this is actually quite difficult to achieve. The new synthetic absorbable monofilaments are made by extrusion and their diameter and strength can be very accurately controlled. Catgut, on the other hand, originates in strands of variable diameter along the length. Each strand must be checked individually to exclude weak segments and graded to determine the minimal cross section. It is then whittled down by machine until the whole strand is the same thickness. The process is painstaking and tedious, involves multiple quality checks and even then filaments may slip through which are weak for their nominal gauge.

The strength required from a suture depends upon what it is expected to achieve. It must be strong enough to maintain tissue apposition for a specified time. Each suture material at a given gauge can be expected to have a certain strength and, if it is absorbable, a characteristic pattern of strength loss with time (Fig. 1.1). Catgut is the least predictable in this respect. Furthermore, the pattern of weakening of a suture over time may be altered by the circumstances in which it is used. For example, thoughtless handling can diminish strength, most commonly if the suture is tangled and a knot allowed to form during stitching or the thread is crushed by the application of a clip. Subsequently the presence of sepsis may hasten dissolution; an example for a braided synthetic absorbable is shown in Figure 1.2 (Kapadia et al, 1983). Fortunately, monofilament synthetic absorbables appear relatively indifferent to the presence of sepsis (see below). Some reports have claimed no change in the rate of breakdown of catgut in an infected field, though clinical experience supports the view that catgut is more rapidly destroyed when pus is present. There is some evidence that polyglycolic acid sutures (Dexon) actually retain their strength longer in the presence of bacterial infection. Acid pH may increase the rate of degradation

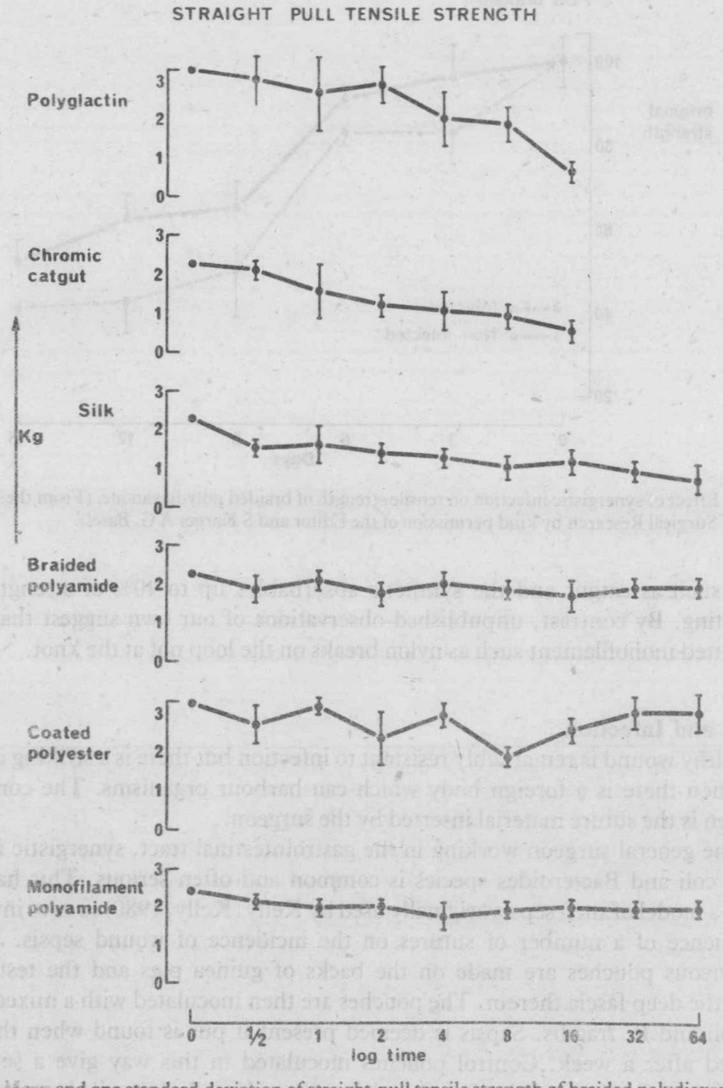

Fig. 1.1 Mean and one standard deviation of straight-pull tensile strength of braided polydioxanone. (Reproduced from the British Journal of Surgery by kind permission of the Editor and Butterworths Ltd).

of catgut at least, so that this suture can disappear completely from the stomach wall within forty eight hours. However, the synthetic absorbables are generally stable at the level of acidity seen in man (Chu, 1981) which means that they can be safely used in this situation.

Straight pull strength is of course only one factor in the surgical equation. Most materials — particularly if they are deformable — lose strength when they are knotted. Deformation at knotting adds to knot security because the strands bed into each other. When choosing a suture the surgeon should recognise that with deformable

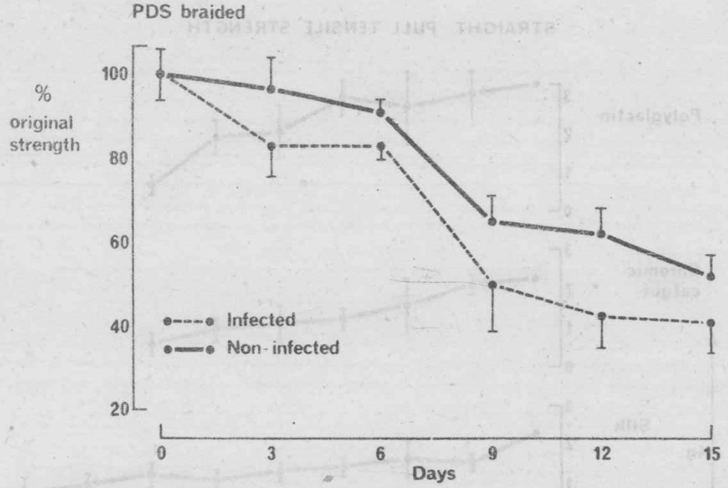

Fig. 1.2 Effect of synergistic infection on tensile strength of braided polydioxanone. (From the European Journal of Surgical Research by kind permission of the Editor and S Karger A G, Basel).

sutures such as catgut and the synthetic absorbables up to 40% of strength is lost by knotting. By contrast, unpublished observations of our own suggest that looped and knotted monofilament such as nylon breaks on the loop not at the knot.

Sutures and Infection

The healthy wound is remarkably resistant to infection but there is a striking enhancement when there is a foreign body which can harbour organisms. The commonest such alien is the suture material inserted by the surgeon.

For the general surgeon working in the gastrointestinal tract, synergistic infection with E. coli and Bacteroides species is common and often serious. This has led us to adapt a model of such sepsis originally used by Kelly (Kelly, 1980) so as to investigate the influence of a number of sutures on the incidence of wound sepsis. Multiple subcutaneous pouches are made on the backs of guinea pigs and the test sutures sewn to the deep fascia therein. The pouches are then inoculated with a mixed culture of E. coli and B. fragilis. Sepsis is deemed present if pus is found when the pouch is opened after a week. Control pouches inoculated in this way give a sepsis rate of 27–30% which is roughly that found in contaminated abdominal surgery when chemoprophylaxis is not used. Catgut, braided nylon, silk, polypropylene, polyglycolic acid and polydioxanone (both braided and monofilament) have been studied. The results are summarised in Figure 1.3: catgut, braided nylon, silk and braided polydioxanone all increase sepsis rates significantly, whereas polypropylene, monofilament polydioxanone and polyglycolic acid appear indifferent. Thus, multifilament sutures in general, with the exception of polyglycolic acid, increased the susceptibility of a wound to infection. Polyglycolic acid is known to produce hydrogen ions on degradation and one possibility is that this would provide an unfavourable environment for bacterial multiplication. Uninfected wounds containing sutures were indeed slightly more acidic but this was not related to suture type and it is unlikely that it is the

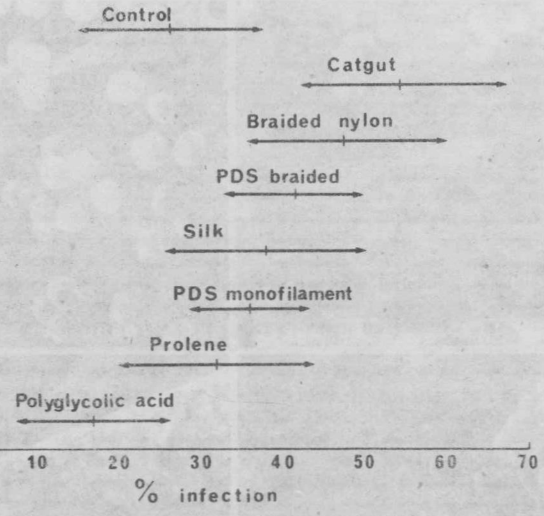

Fig. 1.3 Effect of different sutures on the sepsis rates in innoculated guinea pig pouches. (Reproduced from the British Journal of Surgery, by kind permission of the Editor and Butterworths Ltd).

pH in the environment around a suture that is important in determining whether sepsis will occur.

There does appear to be a relationship between the configuration of a suture (multifilament or monofilament) and its propensity to promote wound infection. Two factors could be important:

1. bacterial adherence to the surface of a suture and
2. the ability of bacteria to gain access to the interstices of a multifilament material.

Workers in Israel (Katz et al, 1981) have used in vitro adherence assays to show that a suture having a high adherence factor for any one bacterium retained the same degree of adherence for all, so suggesting that adherence is a property of the suture. By using radiolabelled bacteria they were able to demonstrate that bacterial clearance from the suture was inversely proportional to initial adherence. Scanning electron microscopy suggests that it is the suture configuration — its filament composition and surface smoothness — that governs the different affinity of materials for bacteria (Fig. 1.4). Braided material had bacteria in its interstices where they may be protected from phagocytosis.

Reactivity

All sutures produce some tissue response. Three components of this can be identified. First, the reaction to injury consequent upon the passage of the material (and of course often a needle as well) through the tissue and which though always mild is determined by the physical properties of the suture. A braided or twisted material will do more harm than a monofilament though various coatings are applied by manufacturers to lubricate the material which incidently can also improve its handling properties. Second, the inflammatory response evoked by the foreign body. Foreign body reaction is greatest for natural materials (catgut, collagen, silk, linen and cotton)

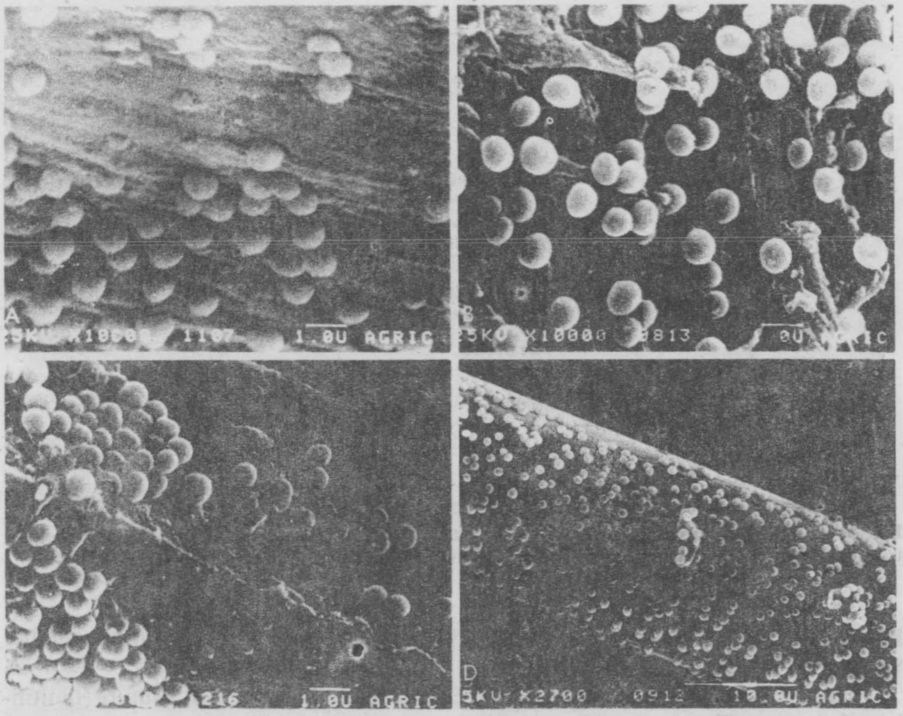

Fig. 1.4 Composite scanning electron micrograph showing staphylococci adherent to surgical sutures. A — monofilament nylon (×10 000); B — chromic catgut (×10 000); C — silk (×10 000); D — Dexon (×2700). (Reproduced by kind permission of Dr S Katz and the Editors of Annals of Surgery).

and more marked with braids than with monofilaments. Third, and merging with the second, is the inflammatory reaction that accompanies the destruction of biodegradeable sutures. The last is particularly severe with plain catgut, marked with chromic catgut and much reduced though not entirely absent with the synthetic materials such as polyglycolic acid and polydioxanone which undergo hydrolysis rather than proteolytic digestion. It is this property of these sutures that makes them particularly attractive as a substitute for catgut.

A final point of interest on the subject of reactivity is that no truly allergic reactions have been seen to suture materials in spite of the fact that especially the natural materials must contain strange and potentially antigenic substances.

Visibility

Each suture should ideally be distinguished at a glance from another so that the surgeon can check in a moment that he has been handed what he wants. In practice this may not be wholly possible because of the limited range of dyestuffs which have passed the stringent tests required to minimise the risk of carcinogenicity and other toxicity. A black braided nylon or polyester suture may thus resemble black silk and the absorbable monofilament polydioxanone (PDS) which is violet may be difficult to distinguish — particularly when coated with blood — from nonabsorbable monofilament which is deep blue. The matter is mentioned not as a criticism of the commercial companies who produce the sutures but as a reminder to surgeons that they have a duty to make a careful check on what is put into their hands.

Brightly coloured or dark sutures are an advantage for suturing in deep cavities; they may be unsuitable for subcuticular work in that the dye can be visible through the skin and make for an ugly scar.

Radio-opaque ligatures (e.g., clips — see below) are useful to delineate the extent of a field that may require postoperative radiotherapy and to mark the site of an anastomosis upon which it is desired to carry out a precise radiological study; they are conversely at the moment a disadvantage if follow-up CT scanning is planned because they scatter the X-ray beam so producing radiological artefacts. The coming generation of scanners and the use of absorbable clips when appropriate will almost certainly eliminate this interference which in practice we have not found to be a serious problem in interpretation.

Handling

An ideal suture should handle in a friendly way, running smoothly through the tissue (a property of monofilaments) and not catching (a tendency of braided absorbables which has been somewhat reduced by suitable coatings). It should have no 'memory' — that is it should not tend to return to the configuation in which it lay in the package and hence tangle, which can be a problem with synthetic monofilaments and conventional catgut (which is after all the natural monofilament). Recently catgut which has less memory has been introduced and improvements of this property in other sutures will doubtless take place. The knots made by any suture should bed down easily and be secure with a minimum number of throws: the first is an outcome of the external smoothness of the suture and braided synthetics such as polyglactin (Vicryl) and polyglycolic acid (PGA-Dexon) do tend to catch particularly on the first throw; the second is, as has already been mentioned, related to the deformability of the suture so that relatively hard material with a memory requires more careful attention to the knot because the strands do not grip each other by deformation and the springyness of the material tends to straighten out the loops of the knot. Optimal knotting technique thus depends on the suture material in use and surgeons should vary their approach accordingly. For example, the half blood knot is a strong and secure way of anchoring a continuous monofilament suture while at the same time keeping the bulk of the knot small (Wattchow & Watts, 1984) but it is not suitable for braided materials that are difficult to bed down smoothly by 'slipping' the suture. Square knots are more secure than the series of half hitches that many of us find it is easy to regress to and most materials will knot securely with three square throws.

Elasticity

Tissues heal and regain their strength at varying rates. Figure 1.5 illustrates the two ends of the spectrum: small bowel, which is initially weak, regains this low tensile strength rapidly because the minimum of collagen is required; fascia by contrast is strong before wounding and time is required for the redeposition and re-orientation of sufficient new material for the original strength to be approximated. In addition