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Medical textiles

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15.1 Introduction

An important and growing part of the textile industry is the medical and related healthcare and hygiene sector. The extent of the growth is due to constant improvements and innovations in both textile technology and medical procedures. The aim of this chapter is to highlight the specific medical and surgical applications for which textile materials are currently used. A variety of products and their properties that make them suitable for these applications will be discussed.

Textile materials and products that have been engineered to meet particular needs, are suitable for any medical and surgical application where a combination of strength, flexibility, and sometimes moisture and air permeability are required. Materials used include monofilament and multifilament yarns, woven, knitted, and nonwoven fabrics, and composite structures. The number of applications are huge and diverse, ranging from a single thread suture to the complex composite structures for bone replacement, and from the simple cleaning wipe to advanced barrier fabrics used in operating rooms. These materials can be categorised into four separate and specialised areas of application as follows:

- **Nonimplantable materials** – wound dressings, bandages, plasters, etc.
- **Extracorporeal devices** – artificial kidney, liver, and lung
- **Implantable materials** – sutures, vascular grafts, artificial ligaments, artificial joints, etc.
- **Healthcare/hygiene products** – bedding, clothing, surgical gowns, cloths, wipes, etc.

The majority of the healthcare products manufactured worldwide are disposable, while the remainder can be reused. According to a survey in the USA during the decade 1980–1990, the growth of medical textile products occurred at a compound annual rate of 11%. It is estimated that the annual growth was around 10% during 1991–2000. In western Europe the usage of nonwoven medical products between 1970 and 1994 rose from 3000 tonnes to 19700 tonnes (Fig. 15.1). The medical
product sales of textile-based items in the USA amounted to $11.3 billion in 1980 and $32.1 billion in 1990. This figure is expected to have reached a staggering $76 billion by the year 2000. The US market for disposable healthcare products alone was estimated to rise from $1.5 billion in 1990 to $2.6 billion in 1999 (Fig. 15.2). In Europe, medical textiles already have a 10% share of the technical textiles market, with 100 000 tonnes of fibre, a growth rate of 3–4% per year and a market of US$7 billion.

Although textile materials have been widely adopted in medical and surgical applications for many years, new uses are still being found. Research utilising new and existing fibres and fabric-forming techniques has led to the advancement of medical and surgical textiles. At the forefront of these developments are the fibre manufacturers who produce a variety of fibres whose properties govern the product and the ultimate application, whether the requirement is absorbency, tenacity, flexibility, softness, or biodegradability. A number of reviews concerning textile materials for medical applications have also been reported elsewhere.

### 15.2 Fibres used

#### 15.2.1 Commodity fibres
Fibres used in medicine and surgery may be classified depending on whether the materials from which they are made are natural or synthetic, biodegradable or nonbiodegradable. All fibres used in medical applications must be non-toxic, non-allergenic non-carcinogenic, and be able to be sterilised without imparting any change in the physical or chemical characteristics.
Commonly used natural fibres are cotton and silk but also included are the regenerated cellulosic fibres (viscose rayon); these are widely used in nonimplantable materials and healthcare/hygiene products. A wide variety of products and specific applications utilise the unique characteristics that synthetic fibres exhibit. Commonly used synthetic materials include polyester, polyamide, polytetrafluoroethylene (PTFE), polypropylene, carbon, glass, and so on. The second classification relates to the extent of fibre biodegradability. Biodegradable fibres are those which are absorbed by the body within 2–3 months after implantation and include cotton, viscose rayon, polyamide, polyurethane, collagen, and alginate. Fibres that are slowly absorbed within the body and take more than 6 months to degrade are considered nonbiodegradable and include polyester (e.g. Dacron), polypropylene, PTFE and carbon.8

15.2.2 Speciality fibres
A variety of natural polymers such as collagen, alginate, chitin, chitosan, and so on, have been found to be essential materials for modern wound dressings.9 Collagen, which is obtained from bovine skin, is a protein available either in fibre or hydrogel (gelatin) form. Collagen fibres, used as sutures, are as strong as silk and are biodegradable. The transparent hydrogel that is formed when collagen is crosslinked in 5–10% aqueous solution, has a high oxygen permeability and can be processed into soft contact lenses.10 Calcium alginate fibres are produced from seaweed of the type Laminariae.11 The fibres possess healing properties, which have proved to be effective in the treatment of a wide variety of wounds, and dressings
comprising calcium alginate are non-toxic, biodegradable and haemostatic. Chitin, a polysaccharide that is obtained from crab and shrimp shells, has excellent antithrombogenic characteristics, and can be absorbed by the body and promote healing. Chitin nonwoven fabrics used as artificial skin adhere to the body stimulating new skin formation which accelerates the healing rate and reduces pain. Treatment of chitin with alkali yields chitosan that can be spun into filaments of similar strength to viscose rayon. Chitosan is now being developed for slow drug-release membranes. Other fibres that have been developed include polycaprolactone (PCL) and polypropiolactone (PPL), which can be mixed with cellulosic fibres to produce highly flexible and inexpensive biodegradable nonwovens. Melt spun fibres made from lactic acid have similar strength and heat properties as nylon and are also biodegradable. Microbiocidal compositions that inhibit the growth of microorganisms can be applied on to natural fibres as coatings or incorporated directly into artificial fibres.

15.3 Non-implantable materials

15.3.1 Introduction
These materials are used for external applications on the body and may or may not make contact with skin. Table 15.1 illustrates the range of textile materials employed within this category, the fibres used, and the principal method of manufacture.

<table>
<thead>
<tr>
<th>Product application</th>
<th>Fibre type</th>
<th>Manufacture system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woundcare</td>
<td></td>
<td></td>
</tr>
<tr>
<td>absorbent pad</td>
<td>Cotton, viscose</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>wound contact layer</td>
<td>Silk, polyamide, viscose, polyethylene</td>
<td>Knitted, woven, nonwoven</td>
</tr>
<tr>
<td>base material</td>
<td>Viscose, plastic film</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>Bandages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>simple inelastic/elastic</td>
<td>Cotton, viscose, polyamide, elastomeric yarns</td>
<td>Woven, knitted, nonwoven</td>
</tr>
<tr>
<td>light support</td>
<td>Cotton, viscose, elastomeric yarns</td>
<td>Woven, knitted, nonwoven</td>
</tr>
<tr>
<td>compression</td>
<td>Cotton, polyamide, elastomeric yarns</td>
<td>Woven, knitted</td>
</tr>
<tr>
<td>orthopaedic</td>
<td>Cotton, viscose, polyester polypropylene, polyurethane foam</td>
<td>Woven, nonwoven</td>
</tr>
<tr>
<td>Plasters</td>
<td>Viscose, plastic film, cotton, polyester, glass, polypropylene</td>
<td>Knitted, woven, nonwoven</td>
</tr>
<tr>
<td>Gauzes</td>
<td>Cotton, viscose</td>
<td>Woven, nonwoven</td>
</tr>
<tr>
<td>Lint</td>
<td>Cotton</td>
<td>Woven</td>
</tr>
<tr>
<td>Wadding</td>
<td>Viscose, cotton linters, wood pulp</td>
<td>Nonwoven</td>
</tr>
</tbody>
</table>
15.3.2 Wound care
A number of wound dressing types are available for a variety of medical and surgical applications (Fig. 15.3). The functions of these materials are to provide protection against infection, absorb blood and exudate, promote healing and, in some instances, apply medication to the wound. Common wound dressings are composite materials consisting of an absorbent layer held between a wound contact layer and a flexible base material. The absorbent pad absorbs blood or liquids and provides a cushioning effect to protect the wound. The wound contact layer should prevent adherence of the dressing to the wound and be easily removed without disturbing new tissue growth. The base materials are normally coated with an acrylic adhesive to provide the means by which the dressing is applied to the wound. Developments in coating technology have led to pressure sensitive adhesive coatings that contribute to wound dressing performance by becoming tacky at room temperature but remain dry and solvent free. The use of collagen, alginate, and chitin fibres has proved successful in many medical and surgical applications because they contribute significantly to the healing process. When alginate fibres are used for wound contact layers the interaction between the alginate and the exuding wound

15.3 Wound dressings. (a) and (b) wound dressings, (c) wound dressing concept.
creates a sodium calcium alginate gel. The gel is hydrophilic, permeable to oxygen, impermeable to bacteria, and contributes to the formation of new tissue.\textsuperscript{17}

Other textile materials used for wound dressing applications include gauze, lint, and wadding. Gauze is an open weave, absorbent fabric that when coated with paraffin wax is used for the treatment of burns and scalds. In surgical applications gauze serves as an absorbent material when used in pad form (swabs); yarns containing barium sulphate are incorporated so that the swab is X-ray detectable.\textsuperscript{18} Lint is a plain weave cotton fabric that is used as a protective dressing for first-aid and mild burn applications.\textsuperscript{19} Wadding is a highly absorbent material that is covered with a nonwoven fabric to prevent wound adhesion or fibre loss.\textsuperscript{18}

\subsection*{15.3.3 Bandages}

Bandages are designed to perform a whole variety of specific functions depending upon the final medical requirement. They can be woven, knitted, or nonwoven and are either elastic or non-elastic. The most common application for bandages is to hold dressings in place over wounds. Such bandages include lightweight knitted or simple open weave fabrics made from cotton or viscose that are cut into strips then scoured, bleached, and sterilised. Elasticated yarns are incorporated into the fabric structure to impart support and conforming characteristics. Knitted bandages can be produced in tubular form in varying diameters on either warp or weft knitting machines. Woven light support bandages are used in the management of sprains or strains and the elasticated properties are obtained by weaving cotton crepe yarns that have a high twist content. Similar properties can also be achieved by weaving two warps together, one beam under a normal tension and the other under a high tension. When applied under sufficient tension, the stretch and recovery properties of the bandage provides support for the sprained limb.\textsuperscript{18,20} Compression bandages are used for the treatment and prevention of deep vein thrombosis, leg ulceration, and varicose veins and are designed to exert a required amount of compression on the leg when applied at a constant tension. Compression bandages are classified by the amount of compression they can exert at the ankle and include extra-high, high, moderate, and light compression and can be either woven and contain cotton and elastomeric yarns or warp and weft knitted in both tubular or fully fashioned forms. Orthopaedic cushion bandages are used under plaster casts and compression bandages to provide padding and prevent discomfort. Nonwoven orthopaedic cushion bandages may be produced from either polyurethane foams, polyester, or polypropylene fibres and contain blends of natural or other synthetic fibres. Nonwoven bandages are lightly needle-punched to maintain bulk and loft. A development in cushion bandage materials includes a fully engineered needlepunched structure which possesses superior cushion properties compared with existing materials.\textsuperscript{21}

A selection of bandages and non-implantable materials products are shown in Fig. 15.4 and 15.5.

\subsection*{15.4 Extracorporeal devices}

Extracorporeal devices are mechanical organs that are used for blood purification and include the artificial kidney (dialyser), the artificial liver, and the mechanical lung. The function and performance of these devices benefit from fibre and textile
15.4 Different types of bandages and their application. (a) Elasticated flat bandage, (b) tubular finger bandages, (c) tubular elasticated net garment, (d) tubular support bandages, (e) and (f) orthopaedic casting bandage, (g) pressure gloves, (h) pressure garment, (i) hip spica, (j) lumbar/abdominal support, (k) anti-embolism stockings.
15.4 Continued.
technology. Table 15.2 illustrates the function of each device and the materials used in their manufacture.

The function of the artificial kidney is achieved by circulating the blood through a membrane, which may be either a flat sheet or a bundle of hollow regenerated cellulose fibres in the form of cellophane that retain the unwanted waste materials. Multilayer filters composed of numerous layers of needlepunched fabrics with varying densities may also be used and are designed rapidly and efficiently to remove the waste materials. The artificial liver utilises hollow fibres or membranes similar to those used for the artificial kidney to perform their function. The microporous membranes of the mechanical lung possess high permeability to gases but low permeability to liquids and functions in the same manner as the natural lung allowing oxygen to come into contact with the patient’s blood.

15.5 Implantable materials

15.5.1 Introduction
These materials are used in effecting repair to the body whether it be wound closure (sutures) or replacement surgery (vascular grafts, artificial ligaments, etc.). Table 15.3 illustrates the range of specific products employed within this category with the type of materials and methods of manufacture. Biocompatibility is of prime
importance if the textile material is to be accepted by the body and four key factors will determine how the body reacts to the implant. These are as follows:

1. The most important factor is porosity which determines the rate at which human tissue will grow and encapsulate the implant.
2. Small circular fibres are better encapsulated with human tissue than larger fibres with irregular cross-sections.
3. Toxic substances must not be released by the fibre polymer, and the fibres should be free from surface contaminants such as lubricants and sizing agents.

**15.5** Miscellaneous surgical hosiery and other products made from non-implantable materials. (a) Cervical collar, (b) foam padded arm sling, (c) adjustable wrist brace, (d) anti-decubitus boots.
The properties of the polymer will influence the success of the implantation in terms of its biodegradability. Polyamide is the most reactive material losing its overall strength after only two years as a result of biodegradation. PTFE is the least reactive with polypropylene and polyester in between.  

### 15.5.2 Sutures

Sutures for wound closure are either monofilament or multifilament threads that are categorised as either biodegradable or nonbiodegradable. Biodegradable sutures are used mainly for internal wound closures and nonbiodegradable sutures are used to close exposed wounds and are removed when the wound is sufficiently healed.
15.5.3 **Soft-tissue implants**

The strength and flexibility characteristics of textile materials make them particularly suitable for soft-tissue implants. A number of surgical applications utilise these characteristics for the replacement of tendons, ligaments, and cartilage in both reconstructive and corrective surgery. Artificial tendons are woven or braided porous meshes or tapes surrounded by a silicone sheath. During implantation the natural tendon can be looped through the artificial tendon and then sutured to itself in order to connect the muscle to the bone. Textile materials used to replace damaged knee ligaments (anterior cruciate ligaments) should not only possess biocompatibility properties but must also have the physical characteristics needed for such a demanding application (Fig. 15.6). Braided polyester artificial ligaments are

![Anterior cruciate ligament prostheses](image)

**Fig. 15.6** Anterior cruciate ligament prostheses.
strong and exhibit resistance to creep from cyclic loads. Braided composite materials containing carbon and polyester filaments have also been found to be particularly suitable for knee ligament replacement. There are two types of cartilage found within the body, each performing different tasks. Hyaline cartilage is hard and dense and found where rigidity is needed, in contrast, elastic cartilage is more flexible and provides protective cushioning. Low density polyethylene is used to replace facial, nose, ear, and throat cartilage; the material is particularly suitable for this application because it resembles natural cartilage in many ways. Carbon fibre-reinforced composite structures are used to resurface the defective areas of articular cartilage within synovial joints (knee, etc.) as a result of osteoarthritis.

15.5.4 Orthopaedic implants
Orthopaedic implants are those materials that are used for hard tissue applications to replace bones and joints. Also included in this category are fixation plates that are implanted to stabilise fractured bones. Fibre-reinforced composite materials may be designed with the required high structural strength and biocompatibility properties needed for these applications and are now replacing metal implants for artificial joints and bones. To promote tissue ingrowth around the implant a non-woven mat made from graphite and PTFE (e.g. Teflon) is used, which acts as an interface between the implant and the adjacent hard and soft tissue. Composite structures composed of poly(ε-caprolactone) and reinforced with polyglycolic acid have excellent physical properties. The composite can be formed into shape during surgery at a temperature of 60 °C and is used for both hard and soft tissue applications. Braided surgical cables composed of steel filaments ranging from 13–130 μm are used to stabilise fractured bones or to secure orthopaedic implants to the skeleton.

15.5.5 Cardiovascular implants
Vascular grafts are used in surgery to replace damaged thick arteries or veins 6 mm, 8 mm, or 1 cm in diameter. Commercially available vascular grafts are produced from polyester (e.g. Dacron) or PTFE (e.g. Teflon) with either woven or knitted structures (Fig. 15.7). Straight or branched grafts are possible by using either weft or warp knitting technology. Polyester vascular grafts can be heat set into a cramped configuration that improves the handling characteristics. During implantation the surgeon can bend and adjust the length of the graft, which, owing to the crimp, allows the graft to retain its circular cross-section. Knitted vascular grafts have a porous structure which allows the graft to become encapsulated with new tissue but the porosity can be disadvantageous since blood leakage (haemorrhage) can occur through the interstices directly after implantation. This effect can be reduced by using woven grafts but the lower porosity of these grafts hinders tissue ingrowth; in addition, woven grafts are also generally stiffer than the knitted equivalents.

In an attempt to reduce the risk of haemorrhage, knitted grafts have been developed with internal and external velour surfaces in order to fill the interstices of the graft. Another method is to seal or preclot the graft with the patient’s blood during implantation. This is a time-consuming process and its effectiveness is dependent upon the patient’s blood chemistry and the skill of the surgeon. Presealed grafts
have zero porosity when implanted but become porous allowing tissue ingrowth to occur. The graft is impregnated with either collagen or gelatin that, after a period of 14 days, degrades to allow tissue encapsulation. Artificial blood vessels with an inner diameter of 1.5 mm have been developed using porous PTFE tubes. The tube consists of an inner layer of collagen and heparin to prevent blood clot formation and an outer biocompatible layer of collagen with the tube itself providing strength. Artificial heart valves, which are caged ball valves with metal struts, are covered with polyester (e.g. Dacron) fabrics in order to provide a means of suturing the valve to the surrounding tissue.

15.6 Healthcare/hygiene products

Healthcare and hygiene products are an important sector in the field of medicine and surgery. The range of products available is vast but typically they are used either in the operating theatre or on the hospital ward for the hygiene, care, and safety of staff and patients. Table 15.4 illustrates the range of products used in this category and includes the fibre materials used and the method of manufacture.

Textile materials used in the operating theatre include surgeon’s gowns, caps and masks, patient drapes, and cover cloths of various sizes (Fig. 15.8). It is essential that the environment of the operating theatre is clean and a strict control of infection is
Table 15.4  Healthcare/hygiene products

<table>
<thead>
<tr>
<th>Product application</th>
<th>Fibre type</th>
<th>Manufacture system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical clothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gowns</td>
<td>Cotton, polyester, polypropylene</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>caps</td>
<td>Viscose</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>masks</td>
<td>Viscose, polyester, glass</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Surgical covers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>drapes</td>
<td>Polyester, polyethylene</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>cloths</td>
<td>Polyester, polyethylene</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>Bedding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>blankets</td>
<td>Cotton, polyester</td>
<td>Woven, knitted</td>
</tr>
<tr>
<td>sheets</td>
<td>Cotton</td>
<td>Woven</td>
</tr>
<tr>
<td>pillowcases</td>
<td>Cotton</td>
<td>Woven</td>
</tr>
<tr>
<td>Clothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uniforms</td>
<td>Cotton, polyester</td>
<td>Woven</td>
</tr>
<tr>
<td>protective clothing</td>
<td>Polyester, polypropylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Incontinence diaper/sheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coverstock</td>
<td>Polyester, polypropylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>absorbent layer</td>
<td>Wood fluff, superabsorbents</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>outer layer</td>
<td>Polyethylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Cloths/wipes</td>
<td>Viscose</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Surgical hosiery</td>
<td>Polyamide, polyester, cotton</td>
<td>Knitted</td>
</tr>
<tr>
<td></td>
<td>elastomeric yarns</td>
<td></td>
</tr>
</tbody>
</table>

15.8  Surgical garments.
maintained. A possible source of infection to the patient is the pollutant particles shed by the nursing staff, which carry bacteria. Surgical gowns should act as a barrier to prevent the release of pollutant particles into the air. Traditionally, surgical gowns are woven cotton goods that not only allow the release of particles from the surgeon but are also a source of contamination generating high levels of dust (lint). Disposable nonwoven surgical gowns have been adopted to prevent these sources of contamination to the patient and are often composite materials comprising nonwoven and polyethylene films for example.\textsuperscript{16}

The need for a reusable surgical gown that meets the necessary criteria has resulted in the application of fabric technology adopted for clean room environments, particularly those used for semiconductor manufacture. Surgical masks consist of a very fine middle layer of extra fine glass fibres or synthetic microfibres covered on both sides by either an acrylic bonded parallel-laid or wet-laid nonwoven. The application requirements of such masks demand that they have a high filter capacity, high level of air permeability, are lightweight and non-allergenic. Disposable surgical caps are usually parallel-laid or spun-laid nonwoven materials based on cellulosic fibres. Operating room disposable products and clothing are increasingly being produced from hydroentangled nonwovens. Surgical drapes and cover cloths are used in the operating theatre either to cover the patient (drapes) or to cover working areas around the patient (cover cloths).

Nonwoven materials are used extensively for drapes and cover cloths and are composed of films backed on either one or both sides with nonwoven fabrics. The film is completely impermeable to bacteria while the nonwoven backing is highly absorbent to both body perspiration and secretions from the wound. Hydrophobic finishes may also be applied to the material in order to achieve the required bacteria barrier characteristics. Developments in surgical drapes has led to the use of loop-raised warp-knitted polyester fabrics that are laminated back to back and contain microporous PTFE films in the middle for permeability, comfort and resistance to microbiological contaminants.

The second category of textile materials used for healthcare and hygiene products are those commonly used on hospital wards for the care and hygiene of the patient and includes bedding, clothing, mattress covers, incontinence products, cloths and wipes. Traditional woollen blankets have been replaced with cotton leno woven blankets to reduce the risk of cross-infection and are made from soft-spun twofold yarns which possess the desirable thermal qualities, are durable and can be easily washed and sterilised.\textsuperscript{20} Clothing products, which include articles worn by both nursing staff and patients, have no specific requirements other than comfort and durability and are therefore made from conventional fabrics. In isolation wards and intensive care units, disposable protective clothing is worn to minimise crossinfection. These articles are made from composite fabrics that consist of tissue reinforced with a polyester or polypropylene spun-laid web.\textsuperscript{16}

Incontinence products for the patient are available in both diaper and flat sheet forms with the latter used as bedding. The disposable diaper is a composite article consisting of an inner covering layer (coverstock), an absorbent layer, and an outer layer. The inner covering layer is either a longitudinally orientated polyester web treated with a hydrophilic finish, or a spun-laid polypropylene nonwoven material. A number of weft- and warp-knitted pile or fleece fabrics composed of polyester are also used as part of a composite material which includes foam as well as PVC sheets for use as incontinence mats. Cloths and wipes are made from tissue paper
or nonwoven bonded fabrics, which may be soaked with an antiseptic finish. The cloth or wipe may be used to clean wounds or the skin prior to wound dressing application, or to treat rashes or burns.26

Surgical hosiery with graduated compression characteristics is used for a number of purposes, ranging from a light support for the limb, to the treatment of venous disorders. Knee and elbow caps, which are normally shaped during knitting on circular machines and may also contain elastomeric threads, are worn for support and compression during physically active sports, or for protection.

15.7 Conclusions

Textile materials are very important in all aspects of medicine and surgery and the range and extent of applications to which these materials are used is a reflection of their enormous versatility. Products utilised for medical or surgical applications may at first sight seem to be either extremely simple or complex items. In reality, however, in-depth research is required to engineer a textile for even the simplest cleaning wipe in order to meet the stringent performance specifications. New developments continue to exploit the range of fibres and fabric-forming techniques which are available. Advances in fibre science have resulted in a new breed of wound dressing which contribute to the healing process. Advanced composite materials containing combinations of fibres and fabrics have been developed for applications where biocompatibility and strength are required. It is predicted that composite materials will continue to have a greater impact in this sector owing to the large number of characteristics and performance criteria required from these materials. Nonwovens are utilised in every area of medical and surgical textiles. Shorter production cycles, higher flexibility and versatility, and lower production costs are some of the reasons for the popularity of nonwovens in medical textiles.

References