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Medical Textiles: State of Art

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Abstract
Increasingly intimate combination of Textile Technology and Medical Sciences has made an emerging multidisciplinary field with tremendous potential. Medical Textiles represent structures designed and accomplished for a medical application. The number of applications is 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. 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. The medical textile industries have diversified with new materials and innovative designs. Recently, application of textiles has started going beyond the usual wound care, incontinence pads, plasters etc., Latest innovation i.e., wide variety of woven, non-woven, knitted forms of textile increasingly finding their way into a variety of surgical procedures. As the healthcare industry is growing enormously in India, the demand for the Medical Textile is also on the rise. Medical textiles are a major growth area within the technical textile sector and the range of applications for such products continue to grow and increase in diversity with every new development. The introduction of new materials, the improvement in production techniques and fibre properties, and the use of more accurate and comprehensive testing have all had significant influence on advancing fibres and fabrics for medical applications. As more is understood about medical textiles, there is every reason to believe that a host of valuable and innovative products will emerge.

Keywords: Medical, textile, technology, surgical, application

Introduction
Medical Sciences has made an emerging multidisciplinary field with tremendous potential. Medical Textiles represent structures designed and accomplished for a medical application. The number of applications is 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.

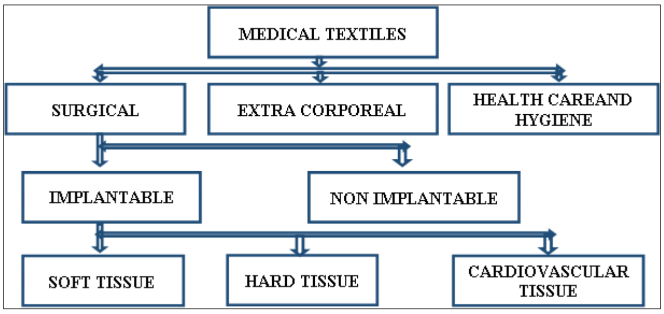
Definitions
- David Rigby Associates, "The Medical Textile application area, embraces all those technical textiles used in health and hygiene applications."
- A/c to Textile Terms and Definitions, "Med tech is a general term which describes a textile structure which has been designed and produced for use in any of a variety of medical applications, including implantable applications.

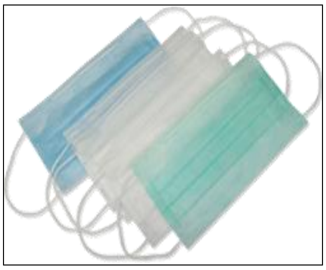
Basic requirement of textile in medical field
- Conformance to technical specifications
- Sterile
- Anti allergic
- Anti-bacterial
- Environment friendly
- Economical
- Elasticity
- Air permeability
- Good dimensional stability
- Biocompatibl

Advantages of textiles in medical field

- Cross infection is reduced
- Protection of care providers
- Cost effective
- WHO recommends disposable Personal Protective Equipments
- The comfort level is higher (eg. Gowns)
- Engineered to have high barriers to blood and other body fluids
- Are flexible, soft and comfortable

Types of medical textiles



(Dorugade, 2015)

Surgical: The surgical products include surgical gowns and surgical masks. Requirements of these are absorbency, breathability, softness, tenacity and bio degradability. In surgical gown the comfort is achieved by the combination of shape or size of garment and ability to maintain satisfactory environment within the garment.

- **Surgical Masks:** It is a medical device covering mouth, nose and chin and providing a barrier to minimize the direct transmission of infective agent from staff and patient. The degree of protection effected by mask depends on filtrations capacity and fit of masks to the wearer face.


Saravanan M (2014) discussed that surgical apparel is identified as a medicinal device intended to be worn by operating room personnel during surgical procedures to protect both the surgical patients and operating room personnel from transfer of microorganisms, body fluids and particulate material. Textile materials have been widely used in medical and surgical applications, but large surface areas and the ability to retain moisture make textile fabrics more prone to bacterial growth. Cross transmission of diseases in hospitals is a major threat. Surgical dressing should not only provide protection against microbial attack, but also have blood barrier properties since most infections are caused by blood borne pathogens.

Extra Corporeal Devices: These are extra corporeally mounted devices used to support the function of vital organs, such as kidney, liver, lung, heart pacer etc. The 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 technology.

Function	Fibre Type	Applications
Remove waste products from the patient’s blood	Hollow polyester fibre, hollow viscose	Artificial kidney
Separate and dispose of patients’ plasma and supply of fresh plasma	Hollow viscose	Artificial liver
Remove carbon dioxide from patients’ blood and supply fresh oxygen	Hollow polypropylene fibre, hollow silicone membrane	Mechanical lung

(Gotipamul and Lokesh, 2014)

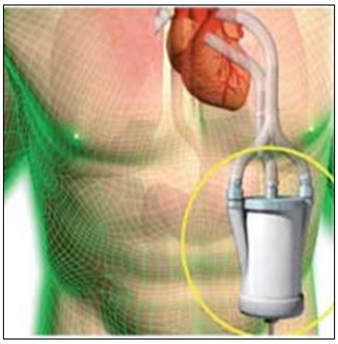
Textile materials for extra corporeal devices

Extra corporeal fibres are those used in mechanical organs such as Hemodialyser (artificial kidney), artificial liver and mechanical lung. Historically, regenerated cellulose fibres in the form of cellophane have been utilized to retain waste products from blood. Japan is the world leader in fibre technology to make ‘Hollow Fibre’ for the artificial kidney. Over the past 20 years, cellulosic membranes have improved considerably due to the ability form:

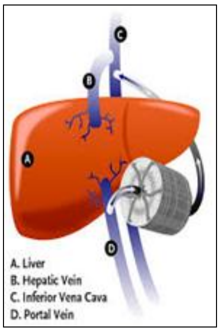
- Thinner membranes
- Controlled pore size
- Improvement of surface properties

Other medical applications of the modified cellulose include hemodialysis membranes (Vit E modified cellulose) and cellulose di-acetate membranes (Chaudhary and Bokar, 2009).

- **Artificial kidney:** The kidneys serve as filtering devices of the blood. The nephrons, the working units of the kidney, filter waste materials out of the blood and produce urine to secrete toxins from body. The kidneys also maintain normal concentrations of body fluids, which play a key role in homeostasis. In the natural kidney, ultrafiltration of the blood occurs through the glomerular capillaries leading to the removal of waste products and the purification of blood. In an artificial unit a membrane-dependent-ultrafiltration achieves essentially the same result. Hemodialysis is indispensable for people suffering from kidney disease. The material used in dialysis membranes are regenerated cellulose, cellulose triacetate, acrylonitrile copolymer, poly (methyl methacrylate), ethylene-vinyl alcohol copolymer, polusulfone and polyamide which can be grouped as cellulose and synthetic polymer systems. Pore sizes of membranes vary between 1 - 3 nm for conventional membranes and 4 - 8 nm for large pore membranes. 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 fibres composed of numerous layers of needle-punched fabrics with varying densities may also be used and are designed to remove the waste materials rapidly and efficiently. The synthetic polymer substitute being experimented with is a polyethylene glycol-polyethylene terephthalate block copolymer membrane which can selectively filter.



- **Mechanical lung:** Mechanical lungs use microporous membranes that provide high permeability for gases (both O_2 and CO_2) but low permeability for liquid flow and functions in the same manner as the natural lung allowing oxygen to come into contact with the patient's blood. During the flow, oxygen, which is maintained at a high partial pressure, displaces carbon dioxide, thus effecting purification. In this device, oxygen flows around hollow fibres at extremely low pressure. Blood flow inside of the fibre. The oxygen permeats the micropores of the fibre and comes in contact with the blood. The pressure gradient between the blood and oxygen is kept near zero to prevent mixing of oxygen and blood. Red blood cells capture oxygen by diffusion process. The mechanical lung was first developed as a device to replace lung function during heart surgery is now, and extensively used for this purpose in the USA (about 250,000 per year) and Japan (20,000 per year). A newer form of artificial lung can also be used as a supplementary respiratory device over a longer term to assist the breathing of patients suffering from acute lung or heart failure, or older people with weak lung function. The best membrane material available and in extensive use is silicone, which not only has a high permeability to gases and low permeability to water but can also be autoclaved. Mitsubishi Rayon Co (Japan) has developed a microporous polypropylene hollow fibre for the manufacture of an artificial lung, and is currently supplying the fibre to medical device manufacturers. Here gases freely pass through the pores of PP hollow fibres, but not the blood, because of the hydrophobicity of PP membrane. As a result, the artificial lung of the gas-bubble type is rapidly being replaced with the membrane type. PP hollow fibre exhibits good compatibility with blood and excellent gas permeability.

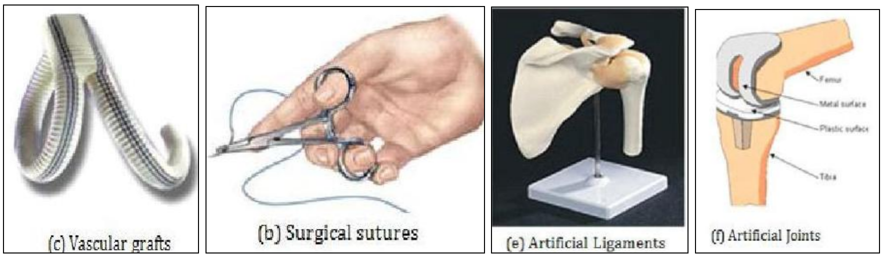


- **Artificial liver:** The artificial liver utilises hollow fibres or membranes similar to those used for the artificial kidney to perform their function. Organ cells are placed around the fibres and blood flows inside the fibre. Blood nutrients pass through the fibre wall to the oxygen cells and enzymes pass from the cells to the blood. The metabolism of the liver is very complicated which poses problems for the artificial liver. This can be solved by using a double lumen structure with a hollow fibre within a hollow fibre. Blood runs outside and in contact with liver cells and blood, and after purification it runs inside the fibre. Unlike the heart, lung or kidneys, which have one primary function, the liver has multiple functions essential to maintain life including carbohydrate metabolism, synthesis of proteins, amino acid metabolism, urea synthesis, lipid metabolism, drug biotransformation and waste removal. Therefore the preferred artificial liver support system would perform these various liver functions. Hepatocytes carry out many vital biological functions, such as synthesis and catabolic reactions, detoxification and excretion. Due to their ability to restore a tissue-like environment, hollow fibre bioreactors (HFBs) show great potential among different systems used to culture hepatocytes. Currently the major use of Hepatocyte Hollow Fibre Bioreactors is as bio artificial livers to sustain patients suffering from acute liver failure, but they can also be used to synthesise cell products and as cellular models for drug metabolism and transport studies. The artificial liver utilises the functions of separating, disposing & supply of fresh plasma in hollow viscose fibres or membranes similar to those used for artificial kidney to perform their function. The principal goal of the Extracorporeal liver assist device (ELAD) is to circulate a patient's plasma extracorporeal through a bioreactor that contains metabolically active hepatocytes. Such devices are expected to increase life of patient, improve the care and quality of life of patients and to reduce care costs.

- **Health Care & Hygiene Products**: An important area of textile is the healthcare and hygiene sector among other medical applications. The range of products available for healthcare and hygiene is vast, but they are typically used either in the operating theatre or in the hospital wards for hygiene, care and safety of the staff and patients. They could be washable or disposable.

Fibre Type	Fabric Structure	Applications
Cotton, polyester fibre, polypropylene fibre	Woven, nonwoven	Surgical gowns
Viscose	Nonwoven	Surgical caps
Viscose, polyester fibre, glass fibre	Nonwoven	Surgical masks
Polyester and polyethylene	Woven, nonwoven	Surgical drapes
Cotton, polyester fibre, polyamide and elastomeric fibre yarns	Knitted	Surgical hosiery
Cotton, polyester fibre	Woven, Knitted	Blankets
Cotton	Woven	Sheets, pillow cases
Cotton, polyester fibre	Woven	Uniforms
Polyester fibre, polypropylene fibre	Nonwoven	Protective clothing
Superabsorbent fibres	Nonwoven	Absorbent layer
polyethylene fibre	Nonwoven	Outer layer
Viscose, Lyocell	Nonwoven	Cloths/wipes

- **Implantable material:** These materials are used in effecting repair to the body whether it is wound closure (sutures) or replacement surgery (vascular grafts, artificial ligaments etc.).



Fibre Type	Fabric Structure	Applications
Collagen, catgut, poly glycolide and Polylactide fibre	Monofilament, braided	Biodegradable Sutures
Polyester fibre, polyamide fibre, PTFE fibre, polypropylene fibre, polyethylene fibre	Monofilament, braided	Non-Biodegradable sutures
PTFE fibre, polyester fibre, silk, collagen, polyethylene fibre, polyamide fibre	Woven, braided	Artificial tendon
Polyester, carbon fibre, collagen	Braided	Artificial ligament
Low density polyethylene fibre Artificial cartilage Chitin	Nonwoven	Artificial skin
Poly (methyl methacrylate) fibre, silicon fibre, collagen		Eye-contact lenses and Artificialcornea
Silicone, polyacetyl fibre, polyethylene fibre		Artificialjoints, bones
PTFE fibre, polyester fibre	Woven, knitted	Vasculargrafts
Polyester fibre	Woven, knitted	Heart valves

Manjunath and Karthik (2014) [6] described that vascular grafting is the use of transplanted or prosthetic blood vessels in surgical procedures. As vascular grafts must have specific characteristics, textile structures are usually the materials used for arterial replacement. The most important aspects of an arterial graft are porosity, compliance and bio degradability. A graft should be micro porous to provide a stable anchorage for vascular cells and stimulate cell growth. Most textile grafts are constructed either of PET (Dacron) or PTEF (Teflon).

Singh *et al.* (2015) [8] stated that vascular implants belong to a specialised class of medical textiles. The basic purpose of a vascular implant (graft and stent) is to act as an artificial substitute for a diseased artery. However, the long-term healing function depends on its ability to mimic the mechanical and biological behaviour of the artery. This requires a thorough understanding of the structure and function of an artery, which can then be translated into a synthetic structure based on the capabilities of the manufacturing method utilised. Common textile manufacturing techniques, such as weaving, knitting, braiding, and electros pinning, are frequently used to design vascular implants for research and commercial purposes for the past decades. However, the ability to match attributes of a vascular substitute to those of a native artery still remains a challenge. The synthetic implants have been found to cause disturbance in biological, biomechanical, and hemodynamic parameters at the implant site, which has been widely attributed to their structural design. They reviewed the design aspect of textile vascular implants and compared them to the structure of a natural artery as a basis for assessing the level of success as an implant. The outcome of this work is expected to encourage future design strategies for developing improved long lasting vascular implants.

- **Non Implantable Materials:** These materials used for external applications on the body and may or may not make contact with skin. This includes wound care, bandages, plasters, pressure garments, orthopedic belts etc.

Fibre Type	Fabric Structure	Applications
Cotton, viscose, Lyocell	Non-woven	Absorbent pad
Alginate fibre, chitosan, silk, viscose, Lyocell, cotton	Woven, non-woven, knitted	Wound-contact Layer
Viscose, Lyocell, plastic film	Woven, nonwoven	Base material
Cotton, viscose, Lyocell, polyamide fibre, elastomeric-fiber yarns	Woven, non-woven	Non-elastic, elastic bandages
Cotton, viscose, Lyocell, elastomeric fiber Yarns	Woven, non-woven, knitted	High-support bandages
Cotton, viscose, Lyocell, elastomeric fiber yarns	Woven, non-woven, knitted	Compression bandages
Cotton, viscose, Lyocell, polyester, polypropylene, polyurethane foam	Woven, knitted	Ortho paedic Bandages
Cotton, viscose, plastics film, polyester fibre, glass fibre, polypropylene fibre	Woven, non-woven, knitted	Plasters
Cotton, viscose, lyocell, Alginate fibre, Chitosan	Woven, nonwoven, knitted	Gauze dressing
Cotton Woven Lint Viscose, cotton linters, wood pulp	Non-woven	Wadding
Polylactide fibre, polyglycolide fibre, carbon	Needle punched Nonwoven	Scaffold

Ideal wound dressing

- Maintain a moist environment at the wound/ dressing interface
- Absorb excess exudates without leakage to the surface of the dressing
- Provide thermal insulation and mechanical protection
- Sterile
- Provide bacterial protection
- Preserve an optimum pH value
- Absorb wound odour
- Be non-toxic and non-allergenic

(Karthik and Wasif, 2014) [4]

Wound dressing materials

Dressing Type	Description
Calcium Alginates	Non-woven mass of calcium sodium alginate fibres that form moisture retentive gel on contact with wound fluid, non occulsive, derived from brown sea weed; rope or flat dressing form
Gauze	Absorbent, 100% meshed cotton fabric, available in pads, strips and rolls of either tightly or loosely woven material Used as primary and secondary dressing
Hydrocolloids	Occlusive wafer dressing, containing hydrophilic colloidial particles (pectin, gelatin, elastomers) in an adhesive compound laminated onto a flexible water resistant outer layer Used as secondary dressing
Hydrogels	Semipermeable hydrophilic polymers composed primarily of water or glycerin; available in gel, sheets, or impregnated gauze form requires a secondary dressing
Transparent Films	Adhesive, transparent polyurethane and polyethylene films, semi permeable membrane dressing that is waterproof yet permit oxygen and water vapour to cross the barrier while remaining impermeable to bacteria and contaminants Used as secondary dressing
Semipermeable Film	Sterile sheet of polyurethane coated with acrylic adhesive
Hydro fibre	Soft non-woven pad or ribbon dressing made from sodium carboxymethyl cellulose fibres
Non adherent Contact Layer	Impregnated gauze with woven materials in which petrolatum have been incorporated into the dressing material

Developments in wound care products

- **Silver dressings:** The use of silver to prevent and treat infection in both one of the earliest forms of wound care. As silver does have such a favourable broad spectrum coverage, especially in antibiotic resistant organisms, with little significant toxicity, there have a number of new silver containing wound products developed to capitalize on its wound healing benefits.
- **Negative pressure wound devices**: Advances in the actual device include smaller size, allowing for portable units for home use, increased ability to remove large amount of fluid, the ability of instill fluids in the wound for continuous irrigation, refinements in the foam with more consistent pore sizes, different sponge materials including silver, and increased safety and alarm systems.
- **Advanced dressings**: While plain gauze is still the most commonly used dressing in hospitals today, new wound understanding and technology have produced advanced products that help the body achieve the ideal moist, warm, protected wound healing environment. Impregnated gauze improves upon this by adding zinc, iodine, or petrolatum to help prevent desiccation and provide non adherent coverage.
- **Skin substitutes**: The advances in temporary and permanent coverage wounds have made significant gains with advancing technology in biomaterials and tissue engineering. Bioengineered skin substitutes, both biosynthetic skin substitutes and cultured autologous engineered skin, are available to provide temporary or permanent coverage, with the advantages of availability in large quatities and negligible risk of infection or immunologic issues.
- **Biobrane:** It is a temporary dressing composed of knitted nylon mesh bonded to a thin silicone membrane and coated porcine polypeptides. It is used in clean superficial and middermal depth burns or as coverage for donor sites in split- thickness skin grafting.
- **Trans Cyte:** It is a biosynthetic dressing of a semipermeable silicone membrane on a nylon mesh coated with porcine collagen and newborn human fibroblast cells. It is used as a dressing in superficial burns that do not require skin grafting, or as a temporary cover for excised burns prior to grafting.
- **Derma graft:** It contains neonatal fibroblasts on a bio absorbable polyglactin mesh. The fibroblasts produce dermal collagen, glycosaminoglycans, growth factors and fibronectin to support wound healing. It is a temporary or permanent cover used for excised burn wounds as well as venous ulcers and pressure ulcers.

Lazar (2010) [5] stated that knitted fabrics and knitting technology play very important role on the fields of technical and medical textiles and their importance is ever greater. Experts estimate that their annual consumption is increasing by 38 % in average and it can reach about 24 million tons in 2020. Within this the consumption of each sector is increasing. Roughly one third of the world’s fibre consumption is used for production of technical textiles.

Disposable Medical Textiles: Disposable medical textiles are used for functional applications, designed to be disposed off after use. They are bound by "use and throw" concept. Moreover, specialty textiles are manufactured for healthcare purpose like isolation gown, disposable trousers, liquid resistant laboratory coats, sleeve protector, shoe cover, disposable bed sheets etc. These textiles are durable, lightweight and inexpensive. Woven and non-woven fabrics are used in manufacturing single use textiles. The leading exporters of disposable textile products are China, Turkey and United States.

Types of Disposable Medical Products

1. **Baby Diapers:** These are used to absorb and retain body fluids of infants in period between birth and 24 months. Diapers are essentially made by a sandwich of an absorbent pads between fabric sheets. The technical textile component of the diaper is the non-woven fabric, which prevents fluid leakage and gives diaper the desired shape.
2. **Adult Incontinence Diapers:** These are for people with loss of bladder control, which typically applies to people in the age group of 70 years and more. These are typically made of the absorbent material of cellulose with poly-beads to convert fluid to gel. The non-woven material is placed on top for dry feeling.
3. **Sanitary Napkins:** These absorb and retain menstrual fluid; isolate menstrual fluids from the body. The desired properties include no leakage, no unaesthetic appearance or colour, no odour, no poison, stay in place and comfortable.
4. **Panty Shields:** It protects the wearer's panty from body exudates. The important properties are sufficient absorption capacity, discretion, comfortable to wear.
5. **Tampons:** These absorb and retain menstrual fluid inside the body. Desired properties are no leakage, no odour, easy to insert/remove, softness, stay in place, comfortable to wear.

Factors in World Trade of Medical Textiles

- Population growth rates, particularly in newly developing global regions,
- Changes in demographics, including the ageing of the population,
- Changes in living standards,
- Attitude to health risks; increased awareness of the risks to health from blood-borne diseases and airborne pathogens,
- Ongoing enhancement in product performance,
- The growing dominance of purchasing which demands increasing value for money,
- The increasing share of nonwovens on the medical world market in relation to traditional textile materials.

Recommendations for the development of this sector

- The government should take step to solve power crisis.
- The textile technologists of our country should come forward to encourage the industrialist to set up medical textile manufacturing factory.
- Collaborate with medical textile manufacturing companies of USA, China etc.
- Try to develop educated, skilled manpower.
- Try to ensure proper safety and sound condition of the factories.

Conclusion

- Medical textiles are a major growth area within the technical textile sector and the range of applications for such products continue to grow and increase in diversity with every new development.
- The introduction of new materials, the improvement in production techniques and fibre properties, and the use of more accurate and comprehensive testing have all had significant influence on advancing fibres and fabrics for medical applications.
- As more is understood about medical textiles, there is every reason to believe that a host of valuable and innovative products will emerge.

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