I. Industrial textiles

Textiles are the largest items of application next only to engineering goods, textiles have found wider acceptance in industry, house hold, aerospace and apparel field.. etc. (1)

Today industrial textile has an old tradition, in the 20th century when man-made fibers became available, the range of industrial textiles was rapidly widened by textiles before, These are currently used to produce fabric reinforced constructions, it is only in the last few decades that industrial textiles have become a commonly considered special group of textiles products, (2) where industrial fabric of the textile field has grown more rapidly than house hold textile and apparel approximately 10 percent a year and makes up about 20 percent of the market share of textile products , (3) and structure components as agriculture and forestry materials to protect natural resources and the living environment in transportation and storage in civil and railway engineering in the manufacture of sports leisure goods … etc. (2)

I.1. Classification of industrial textiles

Classification of industrial textiles is a challenging task, classification of industrial textiles can be done in several ways according to the raw material processed, the manufacturing system and production technique, the basis of main industrial textiles groups.

Or the end use (geotextiles, medical textiles, paper machine and clothing…etc

The researcher has chosen to classify the industrial textiles on the basis of the final application, the main reason for this selection was the convenience to the reader.I.1.1. General industrial textiles

This fabric includes reinforcing fibers for protection from hot and cold, electrically conducting textiles, anti-static textiles, netallized products surface , textiles for electronics and data system technology, fiber optics, drive systems, hoses and tile
reinforced pipes, fabrics for timing gears, rigid and flexible containers hollow pneumatic system oil spill absorbing blankets, textile reinforced rubber products, filters abrasive fabric for sand paper, fabric for movie screens, type writer ribbon, sorption system, seals fiber reinforced sealing materials and textiles reinforced adhesive fabrics for luggage laundry textiles.

**I.1.2. Textile structure composites**
This fabric includes textile reinforced lightweight building materials, textiles reinforced structure all parts molded articles and profiles textiles, for use in corrosive media textile reinforced motor and machine parts.

**I.1.3. Textile in sports and recreation**
This fabric includes active wear fabrics, covers for domes and stadiums, stadiums blankets inflatable building for sports, tennis rackets, golf, clubs, football, tennis ball, roller skates, water and snowski ropes, tennis nets, breathable water proof uniforms, tennis court curtanins, fabrics for hunting vests, race car drivers uniforms, fabrics for hot air balloons fabric for sport shoes, fishing nets and line, swimming pool covers and liners, sleeping bags…. etc

**I.1.4. Geotextiles**
Geotextiles are textiles that are incorporated into geo-technical or civil engineering works, Geotextiles is normally taken to refer only to permeable textiles, Geotextiles are normally woven, non woven with few knitted fabric. Geotextiles designed for use as soil filters in hydraulic engineering, draining material enable a more rapid and simple dewatering of wet grounds, stabilization of earth embankments, railway construction, construction of temporary. Roads, construction of embankments, the construction of road ways on gravel sand.. etc

At this moment, new geotextiles products made of three dimensional network fabric are expected to arouse keen interest, these perforated materials, are used primarily for the
stabilization of side slopes inclines and banks, they also offer young plant support and can be used for corrosion protection.\(^6\)

I.1.5. Safety and protective clothing

Safety and protective clothing are the most diverse market within the industrial fabrics industry. It is referred to by many as a niche industry in which safety and protective clothing is a garment or fabric relate item that protects the wearer from life threatening situations, or risk of injury damage. Protective clothing also refers to garment that protect the product or environment from contamination.\(^7\) The safety and protective clothing market is divided into a number of segments including high visibility, abrasion and cut, slash protection ballistics, personal environmental protection. Material protection, anti-contaminants, radiation protection and vacuum and high pressure\(^8\) the last major use and the most complex, is protective clothing particularly proximity crash suits and protective garments for firemen and others exposed to high temperature including workers in steel mills,\(^9\) it also used in microwave guard for technicians, pool covers, cargo nets for trucks and air craft, rock retaining nets, anti-slippage mat, mosquito netting gasketings, soft and hard armor safety nets and tuber for high pressure pipes which could explode, protective covers for machine tools, bath mats, rain wear, grass catcher bags, anti-glare nets, screen in high way medians, building safety and rescue nets.\(^{10}\)

I.1.6. Transportation

This include materials for automotive application, for aerospace industry, marine application, railway vehicles, materials for bicycles, seat belts, air bags, tire card canvas, reinforced interior coverings, textiles for sealing and wall coverings, sound damping, curtain materials, boat and car covers, seat covering materials, fire resistant textiles, hood fabrics, head liners, hoses and drive belts, gaskets and brake ropes linings, textiles in mufflers, seals, insulation materials, cordage, netting, protective covering systems for air craft, floating vessels for making lighter weight and more fuel
efficient air planes, vehicles, faster boats rocket nozzles and ablative heat shield textiles for aerospace program. (11)

I.1.7.Textiles in agriculture

These fabrics include, textiles for landscaping, textiles reinforced plastic and concrete parts, pipes and containers, insect sacks and bird netting covers, belts rope wear, hoses, flexible and rigid containers silage protection system, flexible silos, textile for seed bed protection, temporary agriculture building, subsoil stabilization, soil covering system, drainage and irrigation system, moisture-retaining mats, scrims for protection from hail and ground frost soil sealing systems for liquid manure pits, erosion prevention textiles, protective work clothing shade fabrics, and textiles in green houses (4)

I.1.8.Military and defense uses

Military applications include mufflers to lower noise level, tank armor to protect from burring, anti tanks shells, camouflage nets, sand bags, hamlets, flank gacets and ballistic gear, (10) parachutes for space ships, personnel protection, chemical suits, air condition suits, rescue systems for air, water and land vehicles, marine applications, fabrics for bullet-proof vests, inflatable building, military tents. (4) These fabrics should be stronger, lighter, more durable and resistant to fire, lases, decontamination materials and chemical agents. (12)

I.1.9.Filters

Filters cloth is used in almost all sectors of the national economy, there are two types of filter dry, and wet filters. Both dry and wet filter are made of synthetic or natural fibers, fabric filters are used for milk filter, gravity filter for cans and cooling reservoirs, filter for automatic milking machines connected to piping coolant filtration in grinding machines and milling cutters, oil filters, sugar filters ,distilling filters, the brewing filter, the wine filter, starch filter, mineral oil filter, dairy filters, (2) dust filters, the purification of gases and removal of suspended material from liquids and also for gas and liquid chromate graph, (13) textiles for cleaning and separating of gases and liquid, textiles for hot air, and textiles for filtration in food industry.
I.1.10. Textiles in architecture and construction

These fabrics include reinforcement fibers for concrete and plastics, reinforcing dams, covers for stadiums, textiles sheet products for reinforcement purpose, textiles structural parts, profiles and pipes, textiles for reinforcing and cement bridges, textile reinforced light building materials, textiles drainage systems fabrics, and protect, textiles in public building and convention halls, textiles shuttering materials, textiles facade packing system, textiles roofs and roof sheeting, textiles products for building electric system, insulation against cold heat and noise, tents and tent frames, temporary building, inflatable buildings for ware housing membranes for light weight plane load–bearing structure, pneumatic structure, winter building system, stay ropes, textiles a caustic and systems, owning textiles, textile heating cooling and air-conditioning, textile planting and irrigation systems for terraces roof garden sand and courtyards. (4)
I.1.11. Medical textiles

Medical textiles in the industrial textile field gradually have taken an important role. Medical textiles refer to textile products often used in combination with non textile materials which are used for the medical care of humans and animals and act as protection for personnel and equipment in medical care situation. Medical textiles differ from other textile products in that there is often little scope for diversification and design variation.

The medical textiles section, looked at in its broadest term, is undoubtedly one of the greatest success stories of recent years. The medical and related Hygiene industries have been major users of textile products for many years. The huge growth of medical applications of textiles over the last 12 years or more has mirrored that the development of modern medicine and surgery has not been limited to just the volume of materials used, where medical application in addition to protective medical apparel textiles are used for implant, blood filter and surgical dressing… etc. Today there has been a huge increase in both the size of the market and the variety of product available and most industry leaders at all levels of the distributions network, say that there is potential for new products and application.

Classification of medical textiles

Medical textiles could possible be classified by fiber type or processing route. A classification based on function is more appropriate, classification by function emphasizes aspects and different textile structure, it also emphasizes that some application requires several functions, medical textiles are capable of meeting all requirements of medical application on their own, where medical textiles includes many products with a composite structures.

So it is possible to be classified as follow:
I.1.11.1. **Textiles for implantation** such as (sutures, vascular grafts, fabrics for heart valves and repair, artificial joints, fabric for hernia repair, surgical reinforcement, meshes fibrous bone plates... etc)

I.1.11.2. **Non-implantable materials** such as (bandages, wound dressing, plasters... etc)

I.1.11.3. **Health care and Hygiene products** such as (bedding, protective clothing, surgical gowns, wipe, face masks... etc) \(^{(1)}\)

I.1.11.4. **Textiles in extracorporeal devices** such as( artificial liver, lung...etc) \(^{(4)}\)

Today medical textiles are produced and sold within a strict form of regulation and legislation. Such control is essential to protect patients, medical practitioners and manufactures. \(^{(5)}\)

I.1.11.1. **Textiles for implantation**

These materials used in effecting repairs to the body whether it be wound closures sutures or replacement surgery (Heart prosthesis-artificial ligaments, surgical meshes... etc)

Although the natural way to replace a defective part of the body would be transplantation this is not always possible due to several reasons including availability, performance requirement... etc, Therefore physicians often have to use artificial substitute (biomaterial) such as biotextiles, of origin or synthetic material. A part used to replace a body part is referred to as prosthesis. Although textile materials depend on specific application in general, The biological requirements for a satisfactory artificial implant may be stated as follow: \(^{(18)}\)

1. A suitable artificial surface of the body cells to be easily adhered and grown on.
2. Porosity, which determines the rate at which tissue will grow and encapsulate the implant (implant material should be sufficiently porous.
3. Fiber diameter in general, should be smaller than the cells for their adherence, to make human tissues capable of encapsulating.
4. Biodegradability or biostability depending on the application
5-non-toxicity where fiber polymer or fabrication techniques must be –non-toxic and fibers should be free of contaminants

Table (1-1) illustrate the range of textile materials employed with this category, with the type of materials and method of manufacture

Table (1-1)

<table>
<thead>
<tr>
<th>Implantable Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
</tr>
<tr>
<td>Arteries</td>
</tr>
<tr>
<td>Tendon</td>
</tr>
<tr>
<td>Hernia repair</td>
</tr>
<tr>
<td>Heart valve</td>
</tr>
<tr>
<td>Patches</td>
</tr>
<tr>
<td>Suture</td>
</tr>
<tr>
<td>Ligament</td>
</tr>
<tr>
<td>Bone and joints</td>
</tr>
</tbody>
</table>

The Implantable material must meet mechanical requirements for the particular application biocompatibility for examples requires that the biotextiles must interact, with the host in a controlled and predictable way. In addition to these blood cells cause formation of destructive blood clot. Application of textiles as implant include abdominal wall, artery, biohybrid organs, bone, heart valve and wall, vein, hip, joint, ligament, tendon, trachea…etc

- **Soft tissue implants**
Biomedical materials are used in applications such as soft tissue, artificial protheses, artificial skin, patches, artificial tendon and artificial cornea. The main component of soft tissue is the human organism, therefore artificial implant, with collagen modified surface easily adhere to soft tissue, soft tissue compatible artificial materials include silicone rubber, polyurethane hydrogels, carbon fiber, collagen, silk protein and cellulose chitin. (4)

**-Tendons and ligaments**

Ligaments are the fairly elastic bands of tissue that join bones together, tendons are made of similar tissue. The most commonly replaced ligaments are those of knee. (19) Manmade tendons have made of woven and braided porous structure coated with silicon, but nonwoven fabrics are not suitable as ligament prosthesis because of their lack of strength, woven and knitted structures are used as artificial ligaments. (5) Braiding a carbon fiber core and a polyester sleeve have produced a material for replacing damaged ligaments (20) as well as polyester and carbon fibers were used in twisted, knitted and narrow- woven constructions (21) but braided fabrics with a stress strain behavior similar to a natural tendons or ligament are the most suitable structure where braided polypropylene implant usually consists of several strands that are braided into tape –like structure, A braided carbon fiber implant is typically made up of thirty –two strands of 3,000 fiber each.

The requirements for ligament and tendon implants are both biological (biocompatibility – long – term stability ,and supporting tissue proliferation and bio-mechanical (physiological progressive stress strain), bio-absorbable are preferable for manufacturing of ligaments and tendon . (4) Synthetic material can not match the fatigue resistance of natural tissue with its ability to regenerate itself so a graft should encourage the ingrowth of new collagen to form a new tendon or ligament a successful graft must match the mechanical properties of the original ligament or tendon as closely as possible and must induce adverse tissue reactions. (5)
Finally at the present time, no material has been shown to be ideal tendon where founding problem including the abrasion of the prostheses at the point of entry, leading both to malfunction and excessive tissue response to the debris and the creep of the polymer that radically alters the ability to replicate the natural mechanical response to loads, thereby leading to instability. (22).

**Surgical mesh**
Surgical mesh is used in the abdominal wall after injury or lesion caused by hernia. (23) Prostheses made from micro-porous expanded (PTFE) such as Gore-Tex, soft tissue patch, polypropylene mesh such as (the meadox trelex) where polypropylene is resistant to infection and it is not allergenic. (4) Mesh or fabric substrate made from a knitted non-resorbable polyester which is impregnated or developed with partially cross-linked (resorbable).

The materials are loaded with anti-microbial by soaking prior to suturing to the abdominal wall margin, the porous material is a substrate which is impregnated or other wise associated with suitable substance capable of retaining the anti-microbial agent. In the composite prosthesis structure the antibiotics said to be completely surround the membrane mesh or fabric due to the interlocking (impregnated) nature of the resorbable gelatin and the non-resorbable membrane. (23)

**Sutures**
The use of sutures is one of the most common practices in the medical field and this has direct and great muddrity of the world’s population. (24) Sutures are threads that are used to tie around vessels such as arteries to close them. (5) Sutures are also used to close wounds produced by trauma. (22) They can be classified into two groups (absorbable and non-absorbable). Absorbable sutures are, as the name implies, temporary due to their ability to be absorbed or decomposed by the natural reaction of the body to foreign substances. (25) Absorbable sutures include collagen, catgut, polyglycolic acid, polylactic acid copolymer, and polydioxin.
Absorbable sutures are used internally to stop internal bleeding and are degraded by the body fluid after the healing process (4) non absorbable sutures are not dissolved or decomposed by the body’s natural action. (25)

Non absorbable sutures are divided into natural fibers (silk – cotton) and synthetic fibers (polyester, polyamide, polypropylene, steel, and teflon (22) non-absorbable sutures materials are considered to be unresbed in the body for a long period of time. (4) Sutures are manufactured with a wide variety of parameters, they can be mono-filaments or multi-filaments twisted together spun together or braided , they can also be dyed , undyed, coated, not coated .Taken into consideration in the manufacture and use of sutures are properties such as( stress – strain relationship , tensile strength, flexibility, wettability surface morphology, degradation, thermal properties, contact angle of knots, and elasticity , However a rough surface allows for better knot stability and security due to the friction between the surfaces. Finally it is aid that synthetic materials are better than natural materials in general and mono-filaments are better than braids minimizing the size of the sutures assists in reducing tissue reaction. (25) Suture materials must be sterilized when used by using sterilization methods ( ionizing, radiation and ethylene oxide).(26)

-Biomaterials in ophthalmology
Natural and synthetic hydrogels physically resemble the eye tissue and hence have been used in ophthalmology as soft contact lenses. Soft contact lenses are made of transparent hydrogel with high oxygen permeability, Hard contact lenses are made of (methylmethacrylate) and cellulose acetate but flexible contact lenses are made from silicone rubber. (4)

-Dental application
The necessary requirement for a successful dental implant are fixation in the Jaw bone and formation and maintenance of a suitable permuce cossal seal ,bone ingrowth well occur if relative movement of implants and host elevator bone is limited during the post-implantation healing period. (22)
Biopolymers are used in dental treatment to substitute for defects in tissues. Major requirements of dental polymers include translucence and abrasion resistance insolubility in oral fluid, non-toxicity, relatively high softening point, easy fabrication and repair. The most widely used polymer for dental use is polymethylmethacrylate and its derivatives, and polysulfone.

**Orthopaedic products**
Orthopaedic products in the health care industry include arm sling, surgical collars, knee supports, splints and restraints. These products need to be stable and secure as well as comfortable, they are basically made of cotton and synthetic fibers. Synthetic Orthopaedic cushion bandages retain their cushioning effect in the moist atmosphere between skin and plaster, where non woven orthopedic cushion bandages are used under plaster casts and compression bandage for padding and comfort. They are made of polyester or polypropylene with blends of natural and other synthetic fibers. Light needle punching gives bulk and loft to the structure for greater cushion effect. These products were traditionally, made from cotton.

**I.1.1.2. Nonimplantable materials**
These materials are used for external applications on the body and may or may not make contact with skin.

Table (1-2) illustrate the range of textile materials employed with this category, the fiber used and the principle method of manufacture.

<table>
<thead>
<tr>
<th>Nonimplantable textile materials</th>
<th>Fiber type</th>
<th>Manufacture system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Absorbent pad</strong></td>
<td>Cotton, viscose</td>
<td>Non woven</td>
</tr>
<tr>
<td><strong>Wound contact layer</strong></td>
<td>Silk, polyamide, viscose, polyethylene</td>
<td>Knitted, woven, Nonwoven</td>
</tr>
<tr>
<td><strong>Base material</strong></td>
<td>Viscose, plastic, film</td>
<td>Non woven, woven</td>
</tr>
<tr>
<td><strong>Bandage Simple inelastic</strong></td>
<td>Cotton, viscose, polyamide</td>
<td>Woven, knitted, non woven</td>
</tr>
<tr>
<td>/elastic</td>
<td>elastomeric yarns</td>
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<tr>
<td>---------------------------------</td>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Light support</strong></td>
<td>Cotton, viscose, elastomeric yarns</td>
<td>Woven, knitted non woven</td>
</tr>
<tr>
<td><strong>Compression</strong></td>
<td>Cotton, polyamide, elastomeric yarns</td>
<td>Woven, knitted</td>
</tr>
<tr>
<td><strong>Orthopaedic</strong></td>
<td>Cotton, viscose, polyester, polypropylene, polyurethane, foam</td>
<td>Woven, non woven</td>
</tr>
<tr>
<td><strong>Plasters</strong></td>
<td>Viscose, cotton, polyester, glass, polypropylene,</td>
<td>Knitted, woven, non woven</td>
</tr>
<tr>
<td><strong>Gauzes</strong></td>
<td>Cotton, viscose</td>
<td>Woven, non woven</td>
</tr>
<tr>
<td><strong>Lint</strong></td>
<td>Cotton</td>
<td>Woven</td>
</tr>
<tr>
<td><strong>Wadding</strong></td>
<td>Viscose, cotton, lint, wood pulp</td>
<td>Non woven</td>
</tr>
</tbody>
</table>

-Dressings
Synthetic occlusive wound dressing are used for the treatment of burns, granulation tissue, dermatitis, ulceration, blisters, fissures, herpes, and several other skin condition.\(^{(22)}\) Shallow wound one that involves the loss of the epidermis, produces a scab when allowed to heal naturally without a dressing ,the scab is rigid ,dry, and porous to the oxygen required by the regenerated tissue , but acts as barrier to dirt and infection, the scab is shed when regeneration of the epermis is complete. The natural scab has disadvantages that is oxygen permeability is limited , not flexible, and that it is prone to cracking and damage and hence vulnerable to infection .\(^{(5)}\) Dressing are used for many purposes including protection of the wound from physical damage, covering unsightly wounds , exclusion of infection, absorption of excessive fluids from the wound , preventing of strikethrough (transfer of micro-organisms from the wound to external environment) and improving of patient comfort. Ideally dressing should be soft, pliable, to protect from further injuries, be easily applied and removed, be sterile, lint free and non -toxic. Wound care products are usually made of three layers, wound contact layer, absorbent material and base material. Wound dressing should not also adhere to the
wound allowing easy removal without disturbing new tissue growth.

-Wound dressing categories

Wound dressing might be categorized in several different ways based on composition, form and function.

1-Film dressing

These dressing are transparent adhesive -coated materials that are permeable to gases such as vapor and oxygen, but impermeable to bacteria. Film dressings tend to allow accumulation of large volumes of wound exudate beneath the dressing. Film dressings have been used experimentally with some success to control skin bacteria during surgery. Film dressings are designed as surgical drapes, but typically of polymeric films spread with appropriate polysaccharide dressing.

2-Biological dressings

Biological dressings are at much earlier stage of development than other dressing types, these dressings are coated with treated collagen, the major application of these material is expected to be for sever burns where they may be regarded as a temporary skin substitute and to serve as anti-microbial barrier layer to prevent the loss of body fluids, proteins and electrolytes.

3-Hydrocolloid dressings

Hydrocolloid dressings are easily removed from the healing wound with out damage to the newly formed granulation tissue and new epidermis of the healing site.

-Gauze

Gauze is a light weight fabric of open weave made from carded cotton yarns. Gauze should be soft, pliable and absorbent. Most standard specifications require gauze to be bleached, clean and free from weaving defects, and contain no more of seed coat leaf, or other impurities. Gauzes have been used as the main wound dressing material where it was found that wound heals fast when kept in a moist occlusive
condition. Coated gauze are the most common used, and most Gauzes are made from cotton in the form of a loose plain weave. General Gauze is used mostly as a dressing for direct swabs applications and is also used to treat burns and scalds. Changing a gauze dressing before the wound is healed results in removal of at least part of the scab and may destroy some of the regenerating tissues, causing pain and danger of reinfection associated with changing dressing, so gauze may be impregnated with plaster to immobilize and support broken limbs.

-Bandages
The oldest known use of bandage refers to Sumeria (2100.b.c). The Egyptians have used natural adhesive bandages as early as 4,000 years ago for various medical application. The Bandage can be woven, knitted, nonwoven and elastic or non-elastic.

Classification of bandage
1-Domette bandage
Domette bandage consists of plain weave fabric in which the warp threads are cotton and the weft threads are wool. Woven cotton rolled bandage have several disadvantages, they don’t stretch, low absorbency and they ravel under stress. Nonwoven Bandages made of polyester or polypropylene with blends of natural and other synthetic fiber are used for orthopaedic uses.

2-Stretch (elastic) bandages
Stretch bandages can be made by twisted yarns or elastic yarns and by using knitted or woven structures. Woven stretch bandages are referred to as crepe bandage. Knitted stretch bandages are normally produced as tubes. Elastic bandages are used for sprained wrist and ankle support. Elasticity can also be obtained by using two warp beams during weaving, one under normal tension and the other under high tension. This bandage type is available in various diameters and is used
for holding a dressing on a finger or limb to provide support and comfort.

3- Compression bandage

Compression bandages are used to exert a certain amount of compression for the treatment and prevention of deep thrombosis, leg ulceration and varicose veins, depending on the compression they provide. Compression bandages are classified as light, moderate, high and extra-high compression bandages, they can be woven, warp, or weft knitted. (4) Compression bandage may be made of pure cotton, matt, bright viscose rayon, polyamide, elastomeric and rubber filaments (31)

4- Open-weave bandage

Open – weave bandage consists of cotton cloth of plain weave. It is similar to gauze in structure, It is a porous, disposable… strip of cotton fabric of one continuous length containing no joints, clean, and reasonably free from weaving defects. Bandages are normally supplied in widths of 2 cm, 3 cm, 5 cm, and 7 cm, and in length of three to five meters. Open – weave bandage cloth is most often used to protect dressings, hold them in place and to give them support (15)

Cushioning

Cushioning fabrics are used to distribute mechanical stress evenly in situations where stress concentrations would be harmful, Pressure sores is probably the dominant example of the use of cushioning decubital ulcers arise when tissue is subjected to external pressure for a period of time, with ulcers occurring most rapidly with increasing pressure, such pressure sores can occur in patients recovering from surgery. In the past sheep skin was placed under the patient, to reduce the pressure on the most stress tissue by spreading the weight more evenly, however, sheep skins are naturally limited and are difficult to wash and sterilize. (5)
I.1.11.3. Health care and hygiene products

Protective health care garments

The purpose of protective health care garments is to protect from contamination by blood and other infection fluids. Protective healthcare textiles include operation and emergency room textiles, barrier products, breath membranes, surgeon and nurse, caps, masks, foot wear, coats, etc.

There are two basic requirements for a protective textile garment; it should be affordable, breathable, comfortable, dependable, and effective.

The impact of contagious diseases have made hospitals very cautious about protecting fabrics, the medical profession was once concerned mainly with protecting patients from germs, now they must protect themselves. These precautions have caused an increase in demand for medical products storing.

The protective material has to be waterproof but breathable, and it must allow transmission of moisture vapour. They are usually made of polyurethane, polyester or other copolymers. These garments consist of micro porous membranes which provide comfort by allowing body perspiration to be transmitted from the skin surface to the air through a fabric. Health care garments can be woven, knitted or nonwoven. Health care garment could be washable or disposable. Laboratory tests for health care garments include water repellency, lounderability and strength.\(^{(4)}\)
Tables (1-3) attempts to illustrate the range of textile materials employed with this category, including fiber materials used and their method of manufacture.

### Tables (1-3)

<table>
<thead>
<tr>
<th>Healthcare and Hygiene Textile Materials.</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Application</strong></td>
<td><strong>Fiber Type</strong></td>
<td><strong>Manufacture System</strong></td>
</tr>
<tr>
<td>Surgical clothing Gowns</td>
<td>Cotton, polyester, Polypropylene</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>Capes</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 Drapes</td>
<td>Polyester, polyethylene</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>Clothes</td>
<td>Polyester, polyethylene</td>
<td>Nonwoven, woven</td>
</tr>
<tr>
<td>Bedding Blankets</td>
<td>Cotton, polyester 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 Uniforms</td>
<td>Cotton, polyester Cotton, polyester</td>
<td>Woven</td>
</tr>
<tr>
<td>Protective clothing Uniforms</td>
<td>Polyester, polypropylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Incontinence diaper/stock Coverstock</td>
<td>Polyester, polypropylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Absorbent layer</td>
<td>Woodpulp, super absorbents</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Outer layer</td>
<td>Polyethylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Clothes/wipes</td>
<td>Viscose</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Surgical hosiery</td>
<td>Polyamide, polyester, elastomeric, yarns, cotton</td>
<td>Knit</td>
</tr>
</tbody>
</table>

- **Products used in hospitals**
  Products used in hospitals include bedding clothing, shoes covers, cloths incontinence products, cloths and wipes.

- **Operating room apparel**
  Normal operating room apparel comprises a scrub suit, consisting of trousers and short sleeved tunic, or a dress, this is clean but normally sterile and will normally be worn all day. The traditional material for operating – room apparel is woven.
cotton dyed in green, in some cases. Woven cotton has the advantages of being easy to launder and sterilize and relatively comfortable to wear. All fabric used for operation – room apparel must have antistatic properties.

-Nurse’s apparel

Nurse’s apparel is made of conventional fabrics since no specific requirement is needed other than comfort and durability. These fabrics consist of tissue reinforced with a polyester or polypropylene spun-laid web.

-Surgical mask

Masks often have a multiple layers structure to ensure more efficient filtration of the breath while masks are made of three layers. The middle layer consists of extra fine glass fibers or synthetic micro fibers covered on both sides by an acrylic bonded parallel-laid or wet-laid nonwoven fabrics. The inner layer consists of a melt-blown polypropylene and outer layer which consists a spun-bonded viscos web to provide strength and to prevent the loss of polypropylene fibers. The masks also contain tapes which are sewn to enable them to be tied firmly into place over the nose and mouth. The performance requirements for surgical face masks are high bacterial filtration capacity, high air permeability, light weight and non-allergenic.

-Surgical caps

Surgical caps are often made of cellulosic Fibers, with the paralleled-laid or spun laid process but commonly for surgical spun the surgical cap made in one piece or from two or three pieces sewn to give a better fit.

-Overshoes

Overshoes are usually made in one piece or may by made from two or three pieces sewn together to give better fit. Elastic threads are sewn into the edges of the openings to provide simple efficient closure.
- **Gowns**
Gowns manufacturers are responding to higher demands of protection by producing products with increased barrier level \(^4\). Gowns are often made from polyester cellulose and composite polypropylene fibers, and are supplied in sterile packs and have the additional advantages of being used in the event of major emergency \(^5\). Woven cotton fabrics are traditionally used in some surgical gowns because cotton does not produce static electrical charges that can build up and produce electric sparks, however it may release particles from the surgeon and also generate high levels of dust, also nonwoven surgical gowns are used to prevent sources of contamination.

The general requirements for surgical gowns include liquid repellency, bacterial barrier properties, and aesthetics flame resistance static safety and toxicity \(^4\). The fabrics should also be sufficiently flexible, adequate strength tear resistance and comfort \(^32\).

- **Surgical Drapes**
Drapes are used in the operating room to cover patients and the area around him to reduce the risk of the wound becoming contaminated by skin cells shed by the patient \(^4\). Drapes are made from woven cotton or linen, and usually supplied cut to a variety of different shapes appropriate to different surgical procedures and contain an opening according to the position of the surgical site \(^5\). They could also be made of non-woven fabrics are used as backing material on one or both sides of a film, while the film is impermeable to bacteria. Nonwoven backing is high absorbent to both body perspiration and secretions from the wound. The general requirements for surgical drapes include liquid repellency bacterial barrier, conformability, tactile softness, comfort, strength, fiber tie-down properties lint propensity and abrasion resistance, flame resistance, static safety and toxicity \(^4\).

- **Bedding**
The bedding is used in the sense of body whose breath is large in comparison with its thickness, the flexible web may be
woven or laid down as a nonwoven fabric. It is preferred that the web be permeable to aid the deposition besides that it can allow access of air to the encased limb. The web most preferably has a porous structure and in the case of woven or non-woven fabrics, the porosity of the web may be conditioned by the method of manufacture, so that this particular characteristic may be predetermined to insulate the burned tissues of the patient from the patient for the purpose of covering him to prevent exposure may be required it.

-Wipes and cloths
Cloths and wipes are used to clean wounds prior to wound dressing or to treat rashes and burns. The wiper is produced by forming a web of nonwoven materials in desired conventional fashion, saturating the web either before or after dying with a liquid solution of the binder material in solvent to cause a pick up by the web of a desired amount of the binder material. The wipe must be capable of retaining .The premoistened wiper which is capable of providing high wet strength until used, the premoistened wiper has a nonwoven web substrate of fibers which are bonded together by polymeric adhesive.

-Surgical swabs
A swab is an absorbent textile pad used in general surgery to prepare the site of the operation to absorb excess blood and body fluids, to pack body cavities during surgery and to clean the incision prior to suturing. The traditional swab which is made of cotton gauze suffers from disadvantages despite its widespread use. The advantages of traditional swabs, in particular are their high absorbency and non linting properties.

-Lint
Lint is a plain weave cotton fabric that is frequently used in the treatment of mild burns. Lint consists of 50/50 polyester blended and tightly woven into fabric. It has a durable, moisture resistance and static control finish, it has also proven to be comfortable to wear. Other properties include abrasion resistance, good tensile strength, fast drying and reusability.
-**Surgical towels**
Nonwoven disposable towel have high absorptive capacity and excellent drying ability with minimum of moisture strike-through. Surgeon may have from about 15 to about 30 grams, of water remaining on his hands and arms after the scrubbing operation, this towel has an absorptive capacity of about 4 to about 7 grams of water and weights, about 30 grams surgeon’s. The towel is must be demonstrating excellent abrasion resistance, strength, sturdiness and at the same time it must be soft

-**Incontinence and hygiene products**
Incontinence is normally regarded as a problem of the very young, the very old and the disabled or bedridden. There are number of incontinence suffer of all ages, the main problem is that of urinary incontinence with stress (caused by laughing, sneezing exertion or emotional upset). Product designs need to meet the different levels of incontinence according to different levels of activity from fully active to chair bound or bedridden. Incontinence protection must not leak, or cause discomfort or skin irritation to the patient.

-**Nappies (diapers)**
The types of nappies or diapers vary greatly through out the world from reusable cloth to the modern disposable type. Disposable diapers and similar have been manufactured using one or more layers of cellulose tissue which makes the diaper relatively stiff. Reusable nappy is made from woven terry cloth which is a woven, warp-pile cotton fabric covered on both sides with uncut loops. The cloth can vary in thickness and weight according to the thickness and quality of the yarn used and the density of the structure. Reusable nappies need to be changed, washed and dried.
Reusable napes can be classed into:

1-**One layer diaper**
One-layer diaper has the problem that all the moisture stays evenly distributed through the diaper so that a high amount of urine remains in direct contact with the baby’s skin and can cause diaper rash.
2-Multi layer diaper
Multi-layer diaper using 100% cotton for skin contact layer and synthetic nonabsorbent layer of polyester or equivalent to provide a wicking action to draw and hold moisture away from the skin.

3-A five –layers diaper
A five layers construction present the deal balance of comfort. The first layer is an interior shell of 100% cotton, the second layer is 100% synthetic nonwoven bonded mono-filament which allows moisture to pass through to the lower layers, the third layer is a 100% cotton wetting pad for maximum additional absorbency with minimum bulk, next is a layer of terry cloth in a cotton/ polyester blend, for extra absorbency. The fifth layer five is also a terry cloth of similar blend to give a panty-like dressed appearance.

-Sanitary towels
There are no standard specifications for producing sanitary towels. A small scale reusable sanitary towels tend to consist of a piece of absorbent cotton fabric. Plain woven cotton or terry cloth is appropriate for reusable sanitary towels where a wrapping absorbent cotton wool with gauze are used to form a pad, and a thin, impermeable layers such as polyurethane, is applied to one side of the cotton wool pad, the pad is then wrapped in a piece of gauze or introduced into a thin, open knitted tube and stitched or knotted at both ends and packaged.

Anti-thrombosis Stockings (surgical hosiery)
Surgical hosiery materials possess compression characteristics and are used for various applications, including support to the limb, treatment of venous disorders, protection in physical actives, etc, where it estimated that 20% of people suffer from problem associated with veins in their legs which can lead to disorders such as varicose, oedemas and thrombosis. Anti-thrombosis stockings are used as a means of preventing the formation of thrombosis as the compression exerted causes narrowing of the veins in the leg. Anti thrombosis stocking has an almost conical tubular construction—,
innovation anti-thrombosis stocking is that it is now produced in a warp–knitted construction using a double–face–double–bar Rachel machine. Stockings are used when a thrombosis has already formed and they have to be made to suit each patient individually according to the compression needed. (23).

I.1.1.4. Textiles for extracorporeal biomedical devices

Textile materials are used in mechanical organs such as artificial kidneys, artificial livers and mechanical lungs (blood oxygenator) for blood purification. In the artificial kidney, blood is circulated through membrane that retains unwanted waste materials, the membrane may be a flat sheet or a bundle of hollow regenerated cellulose fibers in the form of cellophane. Multi-layer fabrics, made of several layers of needle punched fabrics with different densities are also used in artificial kidney. Blood purification is an effective thereby for incurables such as renal failure. It is used to correct the abnormality of blood quality and quantity. Mechanical lungs use micro-porous membranes that provide high permeability for gas flow and low permeability for liquid flow which is similar to the natural lung where oxygen and blood come into contact. In these devices oxygen flows around hollow fibers at extremely low pressure, blood flows inside of the fiber, the oxygen permeates the micro-pores of the fiber and comes in contact with the blood and oxygen is kept near zero to prevent mixing of oxygen with blood. Red blood cells capture oxygen by diffusion process. (4)

Table (1-4) illustrates the function of each device and the materials used in their manufacture.

<table>
<thead>
<tr>
<th>Extracorporeal devices</th>
<th>Fiber type</th>
<th>Manufacture system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial kidney</td>
<td>Hollow viscose, Hollow polyester</td>
<td>Remove waste products from patients blood</td>
</tr>
<tr>
<td>Artificial liver</td>
<td>Hollow viscose</td>
<td>Separate and</td>
</tr>
<tr>
<td>Mechanical ling</td>
<td>Hollow Polypropylene, Hollow silicone, Silicone membrane</td>
<td>Remove carbon dioxide from patients blood and supply fresh oxygen</td>
</tr>
</tbody>
</table>
|----------------|----------------------------------------------------------|-----------------------------------------------------------------
|                | dispose patients plasma, and supply fresh plasma          |                                                                  |
Heart prosthesis
A Prosthesis is a device that is used to overcome surgically some deficiency in the body. The most common prostheses are vascular, prosthetic heart valves and patches etc (5).

Classification of prostheses
Each prosthesis shall be classified as indicated below

1- synthetic textile
A- knitted
B- woven

2- synthetic non-textile
A- extruded / expanded polymers

3- Biological
A- Allograft
B- Xenograft (35)

Patch
Patches are used to close gaps in the septal wall of the heart. Prosthetic patch has become a widely accept technique for the repair of coarctation (36).
Patch may be either autogenous or synthetic. Synthetic patches may be made from polyester or teflon mesh or tightly woven polyester. The size of the patch is determined by the length of the arteriotomy, and the patch is made large enough to ensure that sutures can be placed in an area of the heart that is free of disease (37). PATCH has been laminated on to the surface of a cardiac pumping diaphragm to maintain a totally biolized surface (22).

The vasculature
The Vasculature consists of arteries, arterioles capillaries and veins. Arteries carry blood away from the heart to all parts of the body, (38) where arteries are made up of layers of smooth
muscle fibers and elastic membrane tissue. Arterioles carry blood into capillary tissues, the smallest vessels, through which exchange take place between the blood and the tissues, whereas veins carry blood back to the heart.

**Vascular grafts**
Vascular grafts have only been a practical reality for about 30 years, surgical techniques and prosthetic technology have been developed rapidly and allowed life and limb saving surgical interventions that many people take for granted, consider that there was no successful surgical for replacement of the aortic aneurysm until synthetic grafts became available. Artificial veins or arteries are used to replace segments of the natural cardiovascular system that are blocked or weakened. Grafts are inserted to bypass the blockages and restore circulation.

**Types of vascular grafts**
Vascular grafts maybe biologic or synthetic. There are three categories of biologic grafts which are autologous grafts, Allografts and heterografts. Autologous grafts (tissues taken from one part of the body and moved to another part)
Allografts or homografts are tissue from one person transplanted into another.
Heterografts are tissues from another species that are transplanted into a human.
Synthetic vascular grafts are produced from polyester or polytetraflouroethylene (teflon) with either woven or knitted structures, as parallel, tepered and bifurcated tubes. The grafts normally incorporate a coloured line along the length of the graft to assist the surgeon in avoiding introducing twist into the graft as it is implanted.

**The ideal graft**
The ideal graft should last a life time and permit blood passage without clotting or infection. The rate should be as close 100% as possible and it should show more compliance. The vessel that is used in replacing. The grafts should be easy to manufacture and store impervious to blood leakage to prevent
excessive blood loss and the development of perigraft hematoma, which can interfere with healing and promote infection. Porosity may be essential for fabrics and other biological grafts.

**Characteristics of the ideal graft**

Reasonably priced - readily available – variety of size – easy to store easy to manufacture – durable (survives repeated sterilization, long life in body) suitable for use in the body (bio compatible – non toxic – non allergenic – non thrombogenic infection resistant easy to handle (easy to pass suture needle – pliable elastic – does not kink).

**Requirements for finished vascular graft**

1- porosity, water permeability, integral water permeability, leakage and water entry pressure.
2- strength
3- length
4- relaxed internal diameter
5- pressurized internal diameter
6- wall thickness
7- suture retention strength
8- kink diameter/ radius.

**The cardiac valve prostheses**

The first clinical use of a cardiac valve prosthesis took place in 1952, when Brcharles Hulngel implanted the first artificial caged ball valve for aortic insufficiency. The first implant of a replacement valve in the anatomic position took place in 1960 since then many different types of heart valve prostheses have been developed and used in general during the past 10 years. The surgical implantation of prosthetic heart valves has become successful. Today there are many different way making prosthetic valves, because of the various complications, which occur with different valves.

**The ideal heart valve should be**

1- be fully sterile at the time of implantation and be non toxic.
2-be surgically convenient to insert near the normal location of the heart.
3-conform to the heart structure (the size and shape of prosthesis should not interfere with cardiac function.)
4-show a minimum resistance to flow to prevent a significant pressure drop across the valve.
5-have a minimal reverse flow necessary for valve closure, so as to keep the incompetence of the valve allow level.
6-show long resistance to mechanical and structural wear belong – lasting (25 years,) and maintain its normal functional performance (most not deteriorate over time)
7-cause minimal trauma to blood elements and the endothelial tissue of the cardiac vascular structure surrounding. The valve should also allow probability for thromboembolic complications without the use of anticoagulants.
8-be sufficiently quiet so as not to disturb the patient
9-produce minimal pressure gradient
10-yield relatively small regurgitation
11-minimize production of turbulence
12-not induce regions of high shear stress
13-contain no stagnation or separation regions in its flow field, especially adjacent to the valve super structure. 

**Infection in open heart**

Infection in open heart is the most serious complication of heart prosthesis. The signs and systems of infection in open heart which should alert the patient and physician, may first be obvious distal to the graft. The patient may have a sudden loss of peripheral pulses associated with chemical changes of pain. Pallor may also exist, systamic signs and symptoms also may result from an infected garft, the patient may have fever ranging from one of a low grade, nature to a very high spikes associated with septicemia and even septic shock. The possibility of the development of an infected graft, particularly when prosthetic material is used as graft must be considered of
fever occur, particularly in the absence of any other obvious source. Other problems may be present such as hemorrhage from the gastrointestinal tract. On the other hand the patient may present with evidence of gross gastrointestinal bleeding.  

**Requirements of heart prosthesis**

Requirements specified for implants with regard to duration of contact with human. Body where the contact medium and the intended biostability of the material are stricter compatibility than those for operating. Theatre textiles and products which are used in direct contact with the central nervous system or in the immediate vicinity of the heart or those which are deliberately dissolved in the body.

The most important general requirement of heart prosthesis is The compatibility of the material to the human body and the ease with it can be sterilized.

**Biocompatibility requirements**

1-no triggering of immunological reactions and allergies
2-no causing of unusual foreign body reaction
3-no cytotoxic reaction.
4-no mutagenic, teratogenic or earunogenic reaction
5-no undesirable biodegradation
6-blood compatibility – no change in blood composition and blood properties (blood clothing haemolysis)
7-wide – lumen textile vascular replacement a cement thrombogenic for intraco - operative sealing
8-sterility
9-freedom from pyrogens
10-adequate stability of the structure (including under long – term loading - tensile- pressure- bending)
11-load- elongation characteristics compatible with the tissue being replaced
12-inter operative length matching of the prosthesis
13-availability in suitable dimensions
I.2.1 Fiber used in medical textiles

Textile materials have been used for medical purposes since earlier times, the huge growth of medical applications of textiles over the last 120 years or so has mirrored, the development of modern medicine and surgery. \(^{(5)}\)

The textile materials in the medical textiles have gradually taken an important role, textiles have found their way into a variety of medical applications \(^{(4)}\) and while textile materials have been used in medical textiles for many years, new uses are still being found. Research utilizing new and existing fibers and fabric forming techniques, is essential if further developments are to continue \(^{(18)}\), so fibers are the basic building blocks of any textile structures and their properties, which will govern the product through the ultimate application. \(^{(4)}\)

- Characteristics of materials for medical use

Properties of fibers depend on their structure especially the original polymer and other technical properties, they also depend on the fiber length, cross section, area, stiffness, wrinkles and surface structure. \(^{(54)}\) The major requirements for biomedical polymers are:

- non-toxicity (non – pyrogenicity, non allergenic respond, non carcinogenesis)
- the ability to be sterilized, elasticity, durability, biocompatibility (bioinert, bioactive), stability, good flexibility as well as the material should be strong, non antigenic … \(^{(4)}\)

I.2.1.1. Classification of fibers used in medical textiles

The raw materials basis in the production of industrial textiles continues to expand rapidly, most spectacular has been the growth in demand for high – performance natural Fiber or synthetic fibers \(^{(2)}\) Fibers used in medicine may be classified depending on whether they are natural or man made fibers. \(^{(18)}\)

- The natural fibers
The natural fiber used in medicine include cotton, silk and catgut

-Natural fibers used in medical textiles

-Cotton
Cotton is a natural fiber, which is highly absorbent, good insulation, low static, and it can be laundered repeatedly, besides it has a high impact strength excellent dimension stability, and good breath ability. It finds wide applications in medical textile such as wound dressings, bandages, bedding, clothing, operating room apparel and drapes, diapers, sanitary pads, wipes, and orthopaedic.

-Silk
Silk has good characteristics such as good resistant to all organic solvents, high strength, high regain soft handle resistance to creasing and good draping, so silk find wide applications in sutures.

-Man -made fibers
Man -made fibers divided into regenerated fiber and synthetic fiber

-Regenerated fibers
Regenerated fibers include cellulosic fiber and hollow fiber

-Cellulosic fiber
Cellulosic fiber is 100 percent cellulose and has the same chemical composition as natural cellulose. Cellulosic is made in different tenacity, regular, medium, and high where high tenacity is used for industrial proposes. Cellulosic has a good hand, comfortable, heat resistant, and high regain, that it contains more than 11% water when it is allowed to come to equal brume with air of relative humidity of 65% at temperature of 20%. Besides it is smooth and soft, non – allergenic, processability and bandability. Cellulosic fibers command the greatest share of medical textiles. Where the absorbency of this material is of importance in many medical
application. where Cellulosic fibers commonly used in wound-dressing material, besides that it is used in nonwoven fabrics for sheets and operating room apparels, it is also used in wipes, medical supplies including bandages diapers, babies disposable nappies and adult incontinence pads.

-Hollow fibers
Hollow fibers used in artificial livers and pancreas organ cells, are placed around the fiber and blood flows inside the fiber, where blood nutrients pass through the fiber wall to the organ cells and enzymes pass from the cells to the blood. Hollow fibers are used for biomedical separation like kidney dialysis blood oxygenation, white blood cell separation. Hollow fibers are also used in artificial lungs and artificial blood vessels.

-Synthetic fibers
Synthetic fibers can be used in many shapes or forms, they can be in the long continuous form (filament) or be chopped into shorter lengths (staple fiber). A great range of properties are available from synthetic fibers and the range of fibers used is greater. Synthetic fibers include polyester, polyamide, polytetrafluoroethylene (PTEF) polypropylene, carbon ... etc.

-Polyamide (Nylon) fibers
Polyamide fibers were the first synthetic fibers to be produced. Nylon fibers have excellent thermal stability, high decomposition temperature, quick drying, resistance to light degradation, dyeability, high tear strength, high strength stiffness, tough abrasion resistance, and good resistance to chemicals and fungi. Nylon fibers are used in large number of medical textiles where it is non-toxic and therefore non-irritating to the skin, thus medical fabrics from nylon are used in stretch terry sheets, bandage, eye compressors, medical under wear and plasters.

-Polypropylene
Polypropylene fibers appear to have general more excitement in recent years than any other major fiber. Properties of this fiber are high abrasion, high tenacity, low moisture absorption but good wickability, resistance to chemicals, insects and microbes, and low pilling tendencies. The main application include coverstock and lightweight fabrics used in nappies or incontinence pads.

-Polymethylmethacrylate (PMMA)
Polymethylmethacrylate (PMMA) has been used for dentures, repair of cranial defects, jaw contour correction, spinal fixation, penile inserts, and testicular implants as bone cement.

-Polyurethane
Polyurethane fibers are widely used in medical applications such as heart valves, heart devices, vasculars, catheters, aortic patch grafts, arterial venous shunts and percutaneous devices. It is also used in gas therapy tubing, blood bags, and blood oxygenation.

-Polyethylene
Polyethylene fibers have advantages properties, such as very good sliding properties, exceptional impact strength even at low temperatures, good cyclical fatigue resistance, good human body compatibility, high stiffness, strength and chemical stability. Light weight, high strength, good flexibility, are some of the obvious reasons for high Performance of these fibers. Polyethylene fibers are widely used in medical applications, where it is used in tubing for carrying blood and for inter-vascular catheters, and disposable operating -room apparel. Ultra-high molecular weight polyethylene is suitable for joint replacement as it permits tissue ingrowth.

-Polyvinylchloride fibers (P.V.C)
Vinylchloride is produced in very large quantities for the production of polyvinylchloride plastics, the resistance and no
flammability of p.v.c fibers have enabled them to find important uses in the industrial textiles such as medical textiles where it is used in bandages, orthopaedic materials and artificial limbs.\(^{(69)}\)

**Carbon fibers**

Carbon fibers have been known at least since 1879. Carbon fibers often referred to as graphite fibers properties of these fibers are high tensile and compressive strength, stiffness, light weight, low coefficient of thermal expansion, good vibration damping, low abrasion and high fatigue resistance, biological compatibility and chemical inertness \(^{(70)}\). Carbon fibers made from polyacrylonitrile precursor is successfully used in repairing damaged tendons and ligaments and in absorptive dressings \(^{(71)}\). Carbon fibers are also successfully used as components of bone plates, hip joint prostheses, ligaments and hydraulic for artificial heart implants. The use of carbon fiber reduces the weight of the limb to a level suitable for enfeebled geriatric patient and provides sufficient strength and durability to an active high weight amputee \(^{(72)}\). Carbon fiber reinforced ligament has been in clinical use for the treatment of interior cure for ligament damage and the resultant knee instability since braiding composite structure \(^{(73)}\).

**Rubber**

Rubber has good flexibility and elasticity, tissue and blood compatibility and is inert and relatively non-toxic \(^{(4)}\). Rubber has been used successfully in surgical binding and hose \(^{(74)}\). It has been used successfully for tubing and shunts, vascular applications, bladders, interocular lenses, plastic catheters and reconstructive surgery replacement of cartilage \(^{(4)}\).

**-Special fibers**

**-Collagen fibers**

Collagen is a biodegradable material obtained from bovine skin. The hydrogel is formed by cross linking collagen in 5 to 15 percent aqueous solution \(^{(4)}\). The transparent hydrogel
which has a high oxygen permeability can be processed into soft contact lenses as well as it is used in coating all fabric used in heart prostheses.\(^{(18)}\)

**-Chitin**

Chitin is a polysaccharide obtained from insect skin, crab and lobster shells. Fibers and fabrics made of chitin can be absorbed by the body and have good healing characteristics. Nonwoven chitin fabrics are used as artificial skin dressings, they adhere well to the body and stimulate new skin formation which accelerate the healing and reduce pain.\(^{(5)}\) Chitin is treated with alkali yields chitosan which can spun into filaments of similar strength to viscose rayon, chitosan is now being developed for slow drug released membranes.\(^{(18)}\)

**-Alginate fibers**

Alginate fibers are a natural polysaccharide extracted, which is effective in wound healing as it is non-toxic and biodegradable. Alginate fibers have been widely used in medical textiles where it is used in wound dressing that can interact with wound exudate to form a moist gel.\(^{(30)}\) Commercially available alginate dressings, such as kaltostat, take up protease’s into the interstitial spaces between the fibers of the fabric which limits the total amount of protease uptake.\(^{(23)}\) The alginate dressings are highly absorbent and because of their gel forming characteristics, they can be easily removed from the wound without damaging the delicate tissue of the newly healed wound surface.\(^{(30)}\)

**-Silver fibers**

Silver fibers have played an important part in the development of medicine, silver is being renewed in a wide variety of biomedical applications where it can prevent the growth of micro-organisms. Silver has a broader spectrum of activity and it is less likely to engender high levels of resistance than most modern antibiotics. Metallic silver is used in a number of
surgical application, both structural devices (cranial support plates structure, aneurysm clips, and tracheotomy tubes) and prostheses (the Jonas silicone – silver penile prostheses). It provides the advantages of good tissue bio-compatibility, with corrosion resistance and pascal strength. (22)

-Polytetrafluoroethylene fiber (PTFE) teflon

Polytetrafluoroethylene is non reactive synthetic material that has been proven safe for long, term human implantation, where the uses of Teflon for heart prostheses was first described by klinner and colleagues in 1962, where they used teflon tube in pulmonary artery. In 1974 Gazzaniqa and co-workers introduced a new technique for aorta pulmonary shunting in infancy by using expanded PTFE, where it was utilized to create a shunt between the aorta and the pulmonary trunk or main pulmonary branch arteries. First attempt for the coarctation of aortic discontinuity in interrupted aortic arch using an expanded PTFE graft was made in September 1977. PTEF consists of long chain carbon molecules in which all available bonds are saturated by fluorine. Teflon is heavy, dark brown in color, and it is not flammable but melts at high temperatures. Teflon has excellent chemical and solvent resistance, excellent electrical characteristics, very low friction coefficients with slippery handle, no moisture and almost no dyeability. Teflon is also non-toxic, high compatibility with the blood soft and very flexible. Teflon fluorocarbon polymer is also made in a thin micro-porous membrane, this membrane with very tiny opening or pores is used in making Gore-tex fabrics which has wide use in operating –room apparel. The uses of teflon are largely in industrial textiles where its properties enabled fibers to be used as artificial arteries and arteriovenous shunts as well as a tip material for shunt where prostheses made from micro-porous polytetrafloroethylene such as Gore-tex. Soft tissue patch or macro-porous mesh made of PTFE, exhibited a low significant
rate of infection when used for abdominal wall reconstruction.\(^{(23)}\)

**Fiber used in this research**

**polyester**

In the late 1950 there was intensive development of synthetic arterial substitute.\(^{(80)}\) Some materials such as nylon clearly deteriorated with time with a risk of aneurysm formation and rupture. Dacron (polyester) appears to be more stable and resistant to long term degradation.\(^{(81)}\) Although depending upon the particular weave or knit and fiber density, there is a continuing small risk of aneurysm formation.\(^{(82)}\) Edward was the first to emphasize the importance of porosity in the construction of these synthetic prosthesis.\(^{(83)}\) Polyester is made by reacting dicarboxylic acid with dihydric alcohol, polyester fibers are produced in many types filament or staple yarns. Polyester has excellent resistance to wrinkling and creasing, besides that abrasion resistance and strength of polyester are excellent.\(^{(57)}\) Polyesters characteristics include high strength, resistance to shrinkage and stretching, quick drying, chemical resistance, melting point 450\(^\circ\) F and heat sealability.\(^{(56)}\) The wide variety of polyester textiles good performance properties and favorable economics have combined to make polyester the fibers most used for industrial applications. Polyester fibers dominate the field of medical fabrics, due to certain characteristics, it is used in disposable diapers and sanitary napkins.\(^{(85)}\) An interesting and important use of polyester is for surgical implants, the pure fiber used for this purpose does not causes physiological reactions and thus it is used in vascular tubes to replace damaged human implants.\(^{(86)}\) It is also used in support of cardiac biological valves, artificial heart, mesh type fabrics to reinforce damaged body tissue, patch grafts and dialysis filters.\(^{(56)}\) It is also used in the repair of the abdominal wall after injury lesion caused by hernia, invasive infection or trauma.\(^{(23)}\)
-Lycra
Lycra is well known example of a segmented that was developed for elastic fiber application. (4) It has good properties such as good abrasion resistance, flexibility and high tenacity. Due to the great tenacity of Lycra it has been used successfully in surgical and support bandages and surgical wraps. (74)

I.2.2. The construction methods used in producing medical textiles
Textile fabric is understood to be an assembly of fibers or yarns that has a substantial surface area in relation to its thickness, the assembly must have a useful mechanical strength. There are three basic categories of textile fabrics, where fabric composed of yarns are the most common category, woven and knitted fabrics belong to this category, as delaces, bobbins, braids, nets, stitch bonded fabrics, scrims and adhesive – bonded or heat bonded threads. Fabrics made directly from fibers are another important group, including three sub-classes of textile products, felts, non woven and wads. Combine bonded fabrics are the general term for the third category of textile fabrics. (56)

I.2.2.1. Woven fabrics
Weaving is one of the oldest industry, woven fabrics are defined as fabrics composed by rectangularity interlaced threads, the warp threads and the weft threads, the warp threads or the warp, are oriented lengthways, in the fabric whereas the weft threads, or the weft have been introduced width ways into the fabric. (2) The particular properties of woven fabrics include a high utilization of the strength and characteristics of the initial fibrous material, a high strength and elongation uniformity, (15) dimensional stability and a fairly good resistance to abrasion.
Woven structures may be conveniently divided into two principal categories as follows. (87)
1-simple structures in which the ends and the picks intersect with one another at right angles such as basket weave, twill weave and stain weave.

**Basket weave**
Basket weave is generally defined as having two or more ends interlaced as a unit with one or more filling yarns, this construction is not so firm as regular plain weaves.

**Twill weave**
The second weave pattern used in the manufacture of fabric is the twill weave, this technique is characterized by diagonal line on the face and often on the back.

**Satin weave**
Satin weave is also known as atlas weave, there are two generic types of satin weave, resulting in weft-faced and warp-faced fabrics; these are called satin/weft and satin/warp. 2-compound structure in which there may be more than one series of ends or picks. The variety of arrangements of yarns in a woven structure can be very wide.

-Narrow fabrics
The narrow fabrics industry is the sector of the textile narrow fabrics enter almost every part of our lives. Narrow fabrics defined as any non-elastic woven fabric 12 inches or less in width. Good warp beams are one of the key requirement for efficient production. The narrow fabric can be manufactured by four main different production techniques by weaving, knitting, splitting (cutting) or adhesive bonding.

**Woven tapes** are made of one or more systems of longitudinal (warps) threads and one or more transverse systems of (weft) threads.

**Knitted tapes** are made of one or more longitudinal or transverse threads system are generally produced by the warp knitting and less frequently by the weft knitting technique.
Split tapes are made by splitting (cutting) a full width of woven or knitted fabric on a special splitting machine or directly on the weaving or knitting machine. Adhesive bonded tapes are made of only one longitudinal system of threads, which is adhesive, bonded. Elastic braids woven or knitted exhibit a high longitudinal elongation and elasticity due to the rubber or spandex threads inserted.

Webbing are distinguished from the tapes described above by greater thickness, stiffness and strength, such webbing are double or tabular fabrics with reinforcing warp yarns lying between the two layers and intersecting them sufficiently to bind the composite structure together forming an integral unit.

Some of applications for narrow fabrics are knickers, elastic shoe laces, name labels, insulation, tape, car seat, belts, lifting slings, belts and braces, mattress tapes, curtain heading tapes, packaging card, lamp shade fringes ceremonial, packaging tapes, venetian blind cords, military webbing’s, parachute ribbons, wiring harnesses lace, edgings and tubes.

I.2.2.2.Braiding

Braiding is extremely an old technique. The ancient Egyptians were familiar with the principles of braiding well over 2000 years ago, and the Incas of south America were making braided textiles over a thousand years ago. The braids structure is the simplest form of fabric formation and is formed by using three or more threads so arranged that they cross the fabric diagonally from side to side and at the same time pass under and over each other there are no warp and filling yarns in the scene of a woven fabric.

Braiding doesn’t require beat-up and shedding the yarns don’t have to go through heddles and reads. Circular braiding, a long-established textile process for forming tubular fabrics,
has been extended to produce a range of structural shapes for composite applications.

**Classification of braiding**

Braiding can be classified as two and three-dimensional braiding.

Two dimensional (hollow braiding) or circular (tubular or round) braids are formed hollow or round a center core. A circular braiding machine consists of two sets of an even number of spools containing the braiding yarns. One set runs clockwise around the center of the machine and the other set turns in the opposite direction, while revolving in opposite directions, the carriers are diverted to pass alternately inside and outside, the clockwise paths cause the two sets of yarns to intersect, producing a tubular braid.

**Flat braiding**

Flat braids are made in the form of a flat strip or tape. In flat braiding, instead of following two continuous paths, the carriers turn around or reverse direction at two given points called terminals and then continue on the opposite track, the track does not complete a circle, the size of braid is governed by the following factors.

1. The number of carriers

   Tubular braiders have an even number of carriers, and flat braiders usually have an odd number of carriers, the minimum number of carriers is three, which gives a basic diamond braids similar to girls plaited hair.

2. The diameter of the yarns.

3. The number of yarns per unit length.

   Three dimensional braiding is relatively new compared to two-dimensional braiding.

**Applications of the braiding**

The use of braided fabrics is increasing, traditional examples of the braid structures for industrial applications are electrical...
wises and cables, harnesses hoses, industrial belts surgical sutures, sporting goods, base ball bats, golf water skis and snow skis.\(^{(4)}\)

**I.2.2.3. Nonwoven fabrics**

A nonwoven is textile structure produced by the bonding or interlocking of fibers or both, accomplished by mechanical, chemical, thermal or solvent means.\(^{(5)}\) The design of nonwoven fabrics can be more effective by changing the process parameters, the web preparation methods, such as carding, unidirectional lapping or cross lapping, air laying (long and short staple) wet laying (short – staple), spun bonding and melt – blowing are important, moreover, the bonding categories and their combinations decide the suitability or applicability of nonwoven products\(^{(182)}\), the main categories are resin bonding, thermoplastic fiber bonding and stitch bonding.

In the resin bonding method, the manner of resin application depends on the end use and may be bath spray or paint, the web is then dried and heat cured at temperatures of 200°F to 400°F depending on the materials used in the thermoplastic fiber bonding. A small percentage of a thermoplastic fibers are added to the higher melting or non-thermoplastic. In the stitch – through operation, the laminated webs may be basted together, a thermoplastic thread would respond to heat treatment by shrinking as it softened to give a more compact structure.\(^{(91)}\)

**I.2.2.4. Knitting**

Knitting technology is one of the most sophisticated technologies in the field of textile processing to develop fabrics from one yarn set.\(^{(92)}\)

In this process the fabric is formed by looping yarns together. There are two basic categories of knitted textiles\(^{(93)}\), according to the manner in which the yarns are interlooped, these are weft knits and warp knits. Although different stitches are used
in these operation, all knitted fabrics have some common features. Knitted structures are porous and permit the free circulation fair and the fabrics are soft knitted fabric are very desirable because they don’t Wrinkle easily. (94)

-Warp knitted fabrics
Warp-knitted structures require a number of threads, each yarn producing a row of loops along the length of the material (95). In warp knitting, the fabric structure profoundly influences the mechanical properties of the fabric, the mechanical properties of warp knit can be engineered to meet specific requirement with greater independence of yarn choice. Warp-knitted fabrics have been used for variety uses, for surgical bandage, artificial arteries, geotextiles, nets, cables, air bags, soil cloths, snow chains, hoses, tires, diaphragms, filters, protective clothing, etc (97).

Warp knits are classified according to the type of equipment employed, the most common types are Tricot, Milanese and Rachel. (98) The tricot stitch is produced using spring needles and one or two guide boors, attachments that guide or shift yarns around the hooked or curved portion of the needles prior interlooping. (94)

The Rachel stitch is one of the most versatile methods for constructing patterned knit fabrics (67) and is produced on a machine that may be equipped with up to thirty guide bars. (94) Milanese knits is a method of producing warp knitted similar to tricot. The resultant fabric is similar, but the machinery is quite different. (98)

-Weft knitted fabrics
In weft or filling knitting, the loops made by each weft thread are formed substantially across the width of the fabric. (56) Filling (weft) knits are characterized by most stretch in the crosswise direction and more stability in the lengthwise direction. Weft knits are mostly produced on large –diameter
circular machines, the circular weft knits may be used in original tubular form or split to open width. \(^{(2)}\)

There are four basic stitches used in manufacturing weft knits.

1. The flat or jersey stitch
2. Pique stitch
3. The interlock stitch

**Double knits**

Double knits are produced by the interlock stitch and by varieties of processes. Double knits, have good dimensional stability and are commonly used in tubular shape, that construction find a variety of applications specially in artificial arteries. \(^{(98)}\)
I.2.2.5. Effect of fabric structure on its properties

The vascular prostheses are formed by woven, knitted Gore-tex, complex weave and nonwoven—knit. Procedures are designed to provide an open lattice structures through which fibrous connective tissues can grow. \(^{(22)}\) Grafts usually have a tube shape, the most widely used fibers are polyester and expand PTFE. Polyester vascular grafts can be woven, knitted, braided or extruded.

The surgeon in avoiding introducing twist into the grafts as it implanted, woven constructions were made as a double cloth on narrow fabric loom to give a circular shape. Mostly plain weave is used with yarns between 50-150 denier. The most important property of a graft is its porosity, woven graft structure are typically less porous than knitted structures which diminishes blood leakage through the interstices, \(^{(4)}\) besides that woven grafts are strong and stiff, this stiffness makes it harder to handle because it does not conform to the tissue and is harder for the surgeon to suture. \(^{(43)}\)

The woven double—velour differs from smooth walled structure in that, the employment of an addition set of textured yarns. The velour graft is softer to handle, moreover, The velour components allow reduction in fabric tightness without diversely effecting permeability, and it provides better attachment to surrounding tissues. \(^{(99)}\) Woven fabrics offer the greatest strength, making them more suitable for high stresses. Typical water permeability of woven grafts are 50-500cc/cm\(^2\)/min.

Knitted prostheses are usually made of single jersey structure on weft knitting whereas Rachel structure is used in warp knitting. Velour structure has a rougher inner surface to encourage better adhesion of the thrombus layer. The roughened surface may be obtained by raising a nap, by knitting a looped pile or by using textured filament yarns. Knitted structures are too porous to be used in the machine state so they get compacted by chemical swelling agents or
thermal processing. (5) Typical water permeability of knitted grafts is 1.000-2.000 cc/cm/min in order to prevent leakage, knitted grafts with internal and external velour surface have been developed. Warp knit grafts and warp knit graft dilated less than the weft knit graft (2)