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A Study on Implantable and Non-Implantable Medical Textile Products

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ABSTRACT

Medical textiles, including non-implantable and implantable ones, play a central role in the contemporary healthcare setting, and they are paramount in treating wounds, regeneration, and controlling infections. Implantable textiles (sutures, vascular grafts, artificial ligaments), etc., are used to stabilize tissues and guarantee their harmless incorporation with a focus on the use of biocompatible materials, such as polyglycolic acid, polyester, and collagen. Textiles that are not associated with implantation, such as bandages, wound dressings, and surgical gowns are based more on the comfort and functionality of the products, using cotton, chitosan, and calcium alginate to achieve the desired absorbency of the bandages and antimicrobial effect of wound dressings and surgical gowns. The processing modus could not be left behind, where 3D knitting allows the production of custom implants and nanotechnology increases the biocompatibility of the implant by coating them with a material such as nanosized silver. That change toward the comfort of patients can be seen in breathable and flexible materials and biodegradable dressings with as little irritation as possible. Biocompatibility is essential in that it is very important and has to be tested strictly to ascertain the safety of implants and other products that need to be skin-friendly but not implanted. The new developments incorporate smart textiles with sensors to monitor in real time, which is likely to achieve a market of 1 billion by 2024, and compostable materials that overcome environmental issues. There is a long-term study of biocompatibility, complications in regulatory stages, and trade-offs between sustainability and performance. It is recommended that biodegradable polymers need to be developed, uniform testing needs to be adopted and collaboration between the disciplines needs to be promoted. This overview emphasizes the disruptive capabilities of medical fabrics as it is important to further innovate to improve the results of patient care and sustainability within the medical industry.

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Introduction

Medical textiles represent an active branch of technical textiles, being made with healthcare purposes in mind and having two subcategories, implantable and non-implantable medical textile product groups. Implantable textiles, including surgical sutures, vascular grafts, artificial ligaments, cartilage, and other tissue replacements are introduced into the body to assist in the repair or regeneration of damaged tissues. Wound dressing non-implantable textiles, such as wound dressing, bandages, surgical gowns, and personal protective equipment, are worn on an exterior and are in contact, or close approximation, with the skin [1]. The use of these textiles is required in clinical settings to close the wound, avoid infections, and keep a patient comfortable.

There is a growing trend to offer more products that are biocompatible, safe, and non-reactive in the body as well as more comfortable, especially on non-implantable products that remain in the body over a long duration. The growth is caused by the growth in raw materials, in the form of biodegradable polymers and natural fibers and complex production mechanics, including 3D knitting

and nanotechnology [2]. The recent trends, identified in Textiles inside, focus on smart textiles and the ability to have embedded sensors that can conduct real-time health tracking as well as sustainable materials that take into consideration environmental issues.

The significance of medical textiles is evidenced by the issue of healthcare in the global community, which manifested itself, in particular, in the COVID-19 pandemic, and emphasized the necessity of comfortable and antimicrobial textiles [3]. Their relevance is also increased by the introduction of smart technologies and the emphasis put on personalized medicine. The purpose of this review is to give an empirical analysis of implantable and non-implantable medical textiles, which entail raw materials, manufacturing techniques/procedures, and the transition toward patient comfort and biocompatibility. It attempts to clarify the area of contemporary innovations and determine the developmental prospects by synthesizing recent studies to fulfill the demands of patients, healthcare providers, and the environment.

Research Method

The current review was formed by conducting a systematic literature review of journal articles, industry literature, and other online resources published since 2018 to be relevant and current. Some of the major search terms were: implantable medical textiles, non-implantable medical textiles, raw materials, manufacturing process, patient comfort, and biocompatibility [4]. To be considered, sources were chosen according to their credibility and depth; that is, peer-reviewed articles hosted by the ScienceDirect platform, sources published by Textile World which is an industry newspaper, and bibliographic reports provided by the PMC.

The specific approach applied was the analysis of publications to get comprehensive information about the materials and processes, trends, and innovations that have the impact of improving patient outcomes. The most recent publications about smart and sustainable textiles, including publications by GreyB, gave a clue about the arising tendencies, and have helped to acquire well-rounded knowledge in the industry [5].

Findings

Raw Materials

Implantable Medical Textiles

Textiles in implants must employ materials that are biocompatible, durable and tend to be biodegradable, so as to help integrate with the body. Important materials are:

Natural Materials: Catgut (sheep intestines), reconstituted collagen, cotton, silk, and linen, mostly applied in surgical sutures because of their historically proven track records [6].

Synthetic Absorbable Polymers: Polyglycolic acid, glycolide-lactide copolymer, polydioxanone, and glycolide-trimethylene carbonate copolymers, sutures, and implants which dissolve in time.

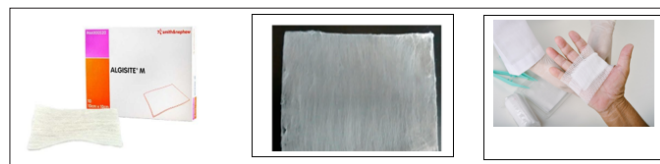
Synthetic Non-Absorbable: polypropylene, polyester (e.g. polyethylene terephthalate, polybutylene terephthalate), polyamide (nylons), Goretex (expanded polytetrafluoroethylene), and stainless steel - long-term implants such as vascular grafts and surgical meshes.

Materials of Artificial Skins: Fibroblasts (neonatal foreskin) and keratinocytes (neonatal foreskin), bovine collagen (calf tendons), and lactic acid (biodegradable mesh scaffolding) [7].

Artificial Cartilage Materials: Kevlar, polyvinyl Alcohol (PVA), and PVA/PVP Hydrogel, which were chosen on the basis of their biocompatibility, and viscoelastic characteristics.

Artificial ligament materials: Polyester, silk, Poly Tetra Fluoroethylene (PTFE), polyethylene terephthalate (PET), carbon fiber covered in collagen and polylactic acid (PLA) to form tissue integration [8].

Anatomic materials are selected with the capacity to reduce immune reactions and tissue regeneration.



Calcium Alginate Wound Dressings Polycaprolactan Nanofibers Dressing Chitosan Dressing

Figure: Non-Implantable Specialized Materials.

Category	Implantable Textiles	Non-Implantable Textiles
Natural Fibers	Catgut, collagen, cotton, silk, linen	Cotton, silk, recycled wood fluff
Synthetic Fibers	Polypropylene, polyester, polyamide, Goretex	Polyester, polyamide, polyethylene, glass fibers
Specialized Materials	Neonatal foreskins, bovine collagen, Kevlar, PVA, PTFE, PET, PLA	Calcium alginate, polycaprolactone nanofibers, chitosan

Table: Specialized Materials [9].

Manufacturing Processes

Non-Implantable Medical Textiles

The textile manufacturing is very specific and under sterile conditions:

Surgical Sutures: Raw polymers are polymerized into pellets, extruded through spinnerets and drawn into the filament (up to 5 times the original length), braided or created into monofilament, annealed (to gain crystalline structure), coated (e.g. Poloxamer 188 absorbable sutures, etc., wax non-absorbable suture), and sterilized in foil packets [10].

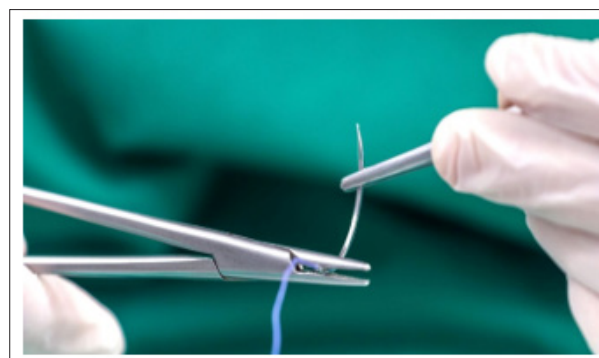


Figure: Surgical Sutures.

Artificial Skin: Mesh scaffolding (fibroblasts cultured on biodegradable mesh for 3-4 weeks) or Collagen (collagen gel, fibroblasts, and keratinocytes, cultured for several weeks).



Figure: Artificial skin [11].

Artificial Cartilage: The generation of non-degradable, biocompatible hydrogels such as PVA /PVP to replicate the viscoelastic properties of cartilage.

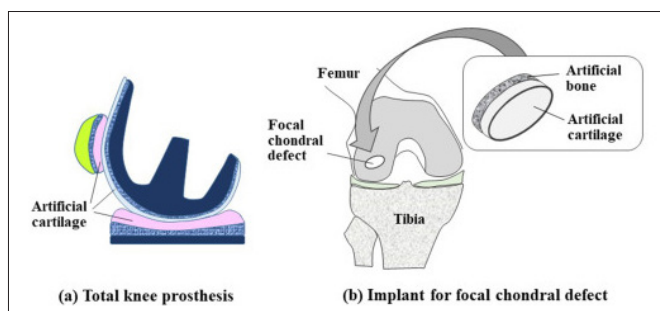


Figure: Artificial Cartilage [12].

Artificial Ligaments: Braiding or weaving fibers such as PET or carbon fiber and then coating them with polymers which are biodegradable and allow the fusion with tissues.

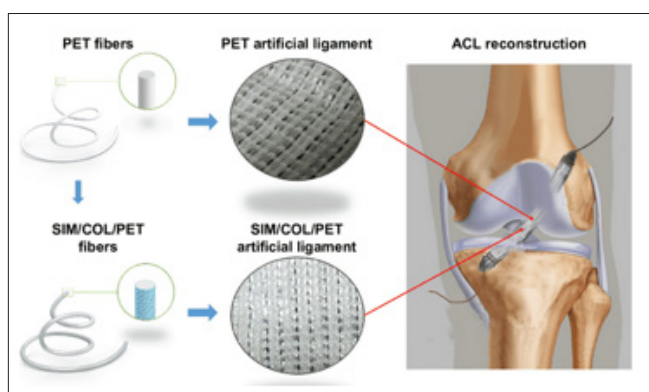


Figure: Artificial Ligaments [13].

Non-Implantable Medical Textiles

What processes are concentrated on: scalability and comfort:

Wound dressings Nonwoven structures absorbency coated with calcium alginate or chitosan [14].

Esophageal Prostheses: Tubular forms of polyglycolic acid weaved and then coated in polycaprolactone nanofiber (Textile Value Chain).

Surgical Gowns and Bandages: Knitted multilayer fabrics to allow breathability and nonwoven production in order to enable absorbency.

Saddled Plasters: elastic two-layered breathable joint structures.

Patient Comfort

Functional design is applied to achieve comfort:

Sutures: They all must be taken out with some time variation between them (e.g., facial surgery 3-5 days, trunk 10-14 days) to avoid pain [15].

Artificial Skin: This creates a replica of natural skin systems to inhibit irritation and stimulate healing.

Artificial Cartilage: Viscoelastic quality increases the mobility of joints and decreases pain.

Artificial Ligaments: (e.g. Leeds-Keio tensile strength 2100N vs. natural ACL 1730N) to provide stability and comfort of artificial ligaments comparable to that of natural ligaments [16].

Biocompatibility

Medical Textiles that are Implanted

Biocompatibility is Safe and Integrative

Sutures: Free of toxin, porous, which promotes tissue growth. Instead, the absorbable sutures disintegrate harmlessly whereas the non-absorbable ones remain insensible [17].

Artificial Skin: Collagen scaffolds have been tested on viruses (e.g. HIV, hepatitis), to ensure safety.

Artificial Cartilage: There are no inflammatory reactions to PVA/PVP hydrogels.

Artificial Ligaments: PLA with carbon fiber and PET encourage tissue growth but it is not rejected [18].

Textiles Non-Implantable Medical Textiles

Biocompatibility is Devoted to Skin-Safety:

Wound Dressing: Chitosan and silver coatings keep them free of infections [19].

Antimicrobial Fabrics: Medication-releasing silk suture and Keri AMD (cotton that has been processed with polyhexamethylene) have antibacterial effects (Textile Value Chain).

Calcium Alginate: reabsorbed or washed away without irritation.

Latest Trends

Newer Developments are More Pleasant and Bio-Compatible:

Smart Textiles: Real-time monitoring sensors (e.g., wound healing bandages, ECG Horst sensors) with a market target of \$1 billion in 2024 (GreyB) [20].

Antimicrobial Textile: Face masks are designed in 70 percent of patients, as washable material with antibacterial characteristics (GreyB).

Biodegradable Fabrics: Eco-friendly materials that decomposed faster to save waste due to the 84-fold hike in mask waste after the pandemic (GreyB).

3D-Knitted Implants: The designs are custom-fit to enhance their functionality [21].

Breathable Clothing: Fabrics that have moisture-absorbent properties to keep the patient comfortable in the hospital.

Discussion

The history of medical textiles indicates that the medical textile industry evolved through important improvements in the sphere of materials science and medical requirements. Natural fibers are historically predominant (cotton and silk), although synthetic and biodegradable polymers, not least polyglycolic acid and PVA show an increasing range of applications because of increased biocompatibility and functionality [22]. In implantable textiles, biocompatibility plays an important role so that the tissues are not rejected, so textiles such as PET and carbon fiber with PLA will encourage tissue integration. Non-implantable textiles focus more on comfort and infection control and they include such materials as chitosan and calcium alginate that can only promote better healing and limit skin irritation [23]. The nature of manufacturing has increased in its sophistication to include 3D knitting which involves complete patient-fit implants as well as nanotechnology which involves coatings of nanosized silver or other materials to increase biocompatibility [24]. Smart textile according to Textiles inside has an inbuilt sensor to monitor in real-time and corrective action helps the patient have better outcomes since early action has taken place. Nevertheless, it is still a challenge to provide sensor reliability, as well as, sensitivity to data privacy.

The ongoing patient-comfort movement is dictated by the necessity of personalized medical care and an increase in the number of chronic conditions. Non-implantable textiles contain breathable clothing and dressings that are biodegradable and plastics that are flexible. All this helps in easing the discomfort. Biocompatibility is achieved by performing stringent testing based on such standards as ISO 10993 (Textile World). Nevertheless, complexity in the supply chain, due to inadequate material transparency, makes compliance difficult [25].

Sustainability is a growing interest, and compostable textile solves the issue of environmental safety. The biodegradable material innovation has been occasioned by the pandemic, and the rise of medical waste, especially those of single-use masks (GreyB). The relationship between performance and eco-friendliness has to be balanced further; more research in this field is needed [26].

The field can also face the problem of Long-term biocompatibility studies of fabric, in particular, implantable textiles, and cost-effective smart textile creation. The harmonization of the regulations in different regions might facilitate the process of innovation and the uniformity of quality. Liaisons with medical professionals, material scientists, and textile engineers make these types of collaborations necessary to solve these problems and advance human knowledge.

To conclude, medical textiles stand on the most innovative level of the healthcare industry, materials, processes, and technologies are highly developed to provide the highest patient comfort and compatibility. Research and interdisciplinary among other activities will keep the field up to date with current healthcare and environmental demands [27].

Recommendation

To promote the process of the medical textile business, the following suggestions are offered:

- **Explore Novel Materials:** Invent new types of materials that can be used to make materials compatible and non-toxic to the

body; biocompatible and biodegradable polymers should be used as implantable textiles to increase their safety and bring them closer to native ones. Priority should have materials that have properties that mimic natural tissues.

- **Standardization of Biocompatibility Testing:** This should be applied to ensure uniformity in the Biocompatibility Testing to ensure that all medical textiles will meet the safety standards especially those to be used in implantation to minimize the chances of unwanted side effects [28].
- **Adopt Smart Technologies:** Continue to proliferate the application of sensor-based fabrics in real-time measurement, e.g. wound healing or vital signs, to better care of patients (GreyB).
- **Sustainability:** Come up with compostable materials that limit medical waste and consider the environmental concerns raised by the growing number of face masks littering after the pandemic (GreyB).
- **Increase Patient Comfort:** Create fabrics that improve the lives of patients with non-allergenic, breathable non-implantable textiles, non-restrictive bandages, and moisture-absorbent medical gowns [29].
- **Interdisciplinary Collaboration:** Promote the cooperation of textile engineers with medical experts and material scientists to enhance innovative development and solve arduous problems.
- **Harmonize Regulations:** Aim at making the world regulated by agreement, and enable easy development and quality across markets.
- The following recommendations can help improve patient outcomes, making their products healthier and more sustainable and establishing medical textiles as a core of future healthcare innovation [30].

Conclusion

Medical textiles, which consist of both implantable and non-implantable products, play a crucial role in contemporary healthcare and help treat wounds, regrow tissues, and prevent infections. Innovations in raw materials, including the likes of natural fibers/ biodegradable polymers and manufacturing technology, including the likes of 3D knitting and nanotechnology are the reason behind advances in biocompatibility and comfort levels to the patients. Up-and-coming tendencies such as sensor-enhanced apparel and compostable materials have a better functionality and sustainability outlook (GreyB). Nevertheless, obstacles such as long-term research on biocompatibility and challenges of regulation are present. The indicators of the future will be interdisciplinary cooperation, standardized assessment, and sustainable creativity. Through the above-mentioned areas, medical textiles will still be able to enhance patient outcomes and quality of life, reassuring their position as an indispensable part of the healthcare field.

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Ethical Statement: Not applicable

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