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SAFETY OF SMART SUTURES WITH SENSORS AND BIODEGRADABLE MATERIALS IN THE HEALING PROCESS: A LITERATURE REVIEW

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Abstract: Objective: To evaluate the safety of smart sutures with sensors and biodegradable materials and to analyze their development in the healing process. Methodology: A literature review was carried out, selecting 11 articles from the PubMed database that met the inclusion criteria. Discussion: The application of materials with conductive and intelligent properties can promote cell adhesion, migration, proliferation and differentiation, contributing to wound healing. These new technologies enable the presence of properties such as wound monitoring, swelling, antibacterial action, hemostasis and regeneration. Thus, a biodegradable suture capable of healing and temperature monitoring in situ, functioning as a wound biomarker, represents a high-level multifunctional platform for improved wound care technologies. However, it is important to consider that the human body can reject or react negatively to most polymers used as electrospray membranes. Furthermore, the use of biodegradable materials in healing has shown to be a promising approach to improve the results of this crucial process in the recovery of damaged tissues. Analysis of the effects of these materials on healing demonstrates improvements in healing strength, reduction of hypertrophic scars, and improved scar esthetics. Conclusion: The use of these technologies promotes efficient healing with greater postoperative safety. However, it is important to understand that the choice of biodegradable material can have specific advantages and disadvantages at each stage of healing.
Keywords: Smart sutures; wound healing; Biodegradable materials.

INTRODUCTION

The adoption of surgical sutures is a widely used strategy to promote efficient healing by approximating tissue edges and reducing scar size. However, the currently available conventional sutures have some limitations regarding mechanical properties, stress distribution and ability to monitor changes in healing. Faced with this growing demand for more advanced techniques in the control of scar recovery, advances have been made in the research of sensors and biodegradable materials, aiming to improve the closure of surgical wounds (PHAN et al., 2021).

The combination of sensors and biodegradable materials with smart sutures and low-cost technologies can provide greater postoperative safety, minimizing complications and allowing accurate monitoring of the healing process. This approach allows the detection of signs such as inflammation, infection and excessive suture tension, in addition to preventing bleeding and wound dehiscence. Studies demonstrate that the application of these new technologies can result in significant benefits, such as non-invasive detection of infections, avoiding the need for painful dressing removal (KHALID et al., 2020).

Therefore, the aim of this literature review is to evaluate the safety of smart sutures with sensors and biodegradable materials, as well as to analyze their ability to detect changes in suture tension and in the healing process. In addition, the effects of these technologies on healing, possible associated complications and the costs involved will be investigated.

METHODOLOGY

This is a bibliographic review developed according to the criteria of the PVO strategy, which means "population or research problem, variables and outcome". The research was elaborated from the following guiding question: "What is the safety of smart sutures with sensors and biodegradable materials in the ability to detect changes in suture tension and in the healing process, as well as their effects on healing, possible complications and costs?". Thus, according to the parameters mentioned above, the population or problem of this research refers to patients who underwent surgical procedures using sensors and biodegradable materials for the healing process. Searches were performed using the PubMed database. Descriptors were used in combination with the Boolean terms "AND" and "OR": "smart sutures and Wound healing or safety or hospital costs", "biodegradable materials and wound healing or safety or hospital costs". The inclusion criteria adopted were: articles in English and Spanish, published from 2018 to 2023, that addressed the themes proposed for this research, including studies of the systematic review type, meta-analysis, literature review, research article and randomized study controlled, provided they are made available in full. Exclusion criteria were: duplicate articles, available only in summary form, that did not directly address the studied proposal and that did not meet the other inclusion criteria. After associating the descriptors used in the searched databases, a total of 958,611 articles were found. Of these, 95,811 articles belonged to the PubMed database. After applying the inclusion and exclusion criteria, 11 articles from the PubMed database were selected to compose the bibliographic review.

RESULTS

SMART SUTURES

Technology is currently advancing in all areas and, especially in medicine, it helps health professionals to work with extreme efficiency and capacity. In this context, smart sutures stand out as promising materials for applications in human body tissue engineering (KAMALATHEVAN et al., 2018). An ideal suture must have adequate tensile strength and be easy to handle, allowing the formation of a secure knot that provides the necessary elasticity and ductility to withstand wound edema and contraction (LEE; KANG, 2021). Recent advances in functional materials have demonstrated the use of synthetic biomaterials, such as poly (lactic-co-glycolic acid) or polydioxanone, as a basis for surgical sutures. However, no single material can suit all surgical applications, as the choice of suture materials is closely related to several factors, such as tissue layers, tension, tissue type, surgical access, and removal time. al., 2023).

Achieving rapid healing, a good aesthetic result and reducing the risk of wound dehiscence depend on an efficient closure of the surgical wound, with the approximation of the skin flaps (MENG et al., 2020; BHANGU et al., 2020). It is evident that the skin, being the largest organ of the human body, maintains an electrolyte balance and the retention of nutritional components, in addition to forming a protective barrier against external factors such as excessive water evaporation, exposure to harmful components and disease-causing pathogens. (KAMALATHEVAN et al., 2018; MENG et al., 2020). Therefore, the reduction of complications related to sutures must be a constant concern in the hospital environment (BHANGU et al., 2020; MENG et al., 2020; KAMALATHEVAN et al., 2018).

The application of materials with conductive and intelligent properties can be used to promote cell adhesion, migration, proliferation and differentiation, contributing to wound healing. This new technology enables the presence of properties such as wound monitoring, swelling, antibacterial action, hemostasis and regeneration (KAMALATHEVAN et al., 2018).

Temperature is one of the specific biomarkers of chronic wounds. Thus, a biodegradable suture capable of healing and temperature monitoring in situ, functioning as a wound biomarker, represents a high-level multifunctional platform for improved wound care technologies. However, it is important to consider that the human body can reject or react negatively to most polymers used as electrospray membranes (NURIA; ALMQUIST, 2020).

The electrospinning of polymers allows the production of 2D or 3D membranes with high porosity and surface area, similar to the extracellular matrix, which makes them suitable as dressings to protect the wound against bacteria, allowing the passage of oxygen and nutrients (NURIA; ALMQUIST, 2020). Electrospinning also resulted in the production of highly porous hybrid silk membranes embedded in NDs (nanodiamonds). These NDs fluoresce inside the silk fibers, adding thermal stability to the material. In vitro tests demonstrated that the surface of these hybrid membranes allows the attachment of eukaryotic cells, promoting the growth of healthy cells. In an in vivo model of wound healing, ND-silk hybrid membranes facilitated healing without adverse effects caused by NDs, which are considered foreign bodies. Furthermore, the addition of NDs prolonged the biodegradation time of silk by 3 to 4 days, and silk and ND-silk membranes showed high efficacy against the main infecting bacteria of cutaneous wounds, such as P. aeruginosa and E. coli (NURIA; ALMQUIST, 2020).

Therefore, hybrid ND silk can be used not only for the detection of infections, but also as a fiber network that supports healthy wound healing. One of the great advantages of this material is the possibility of following the progress of wound healing, providing information to physicians and wound care specialists about the need to change dressings at shorter or longer intervals (NURIA; ALMQUIST, 2020).

BIODEGRADABLE MATERIALS

The use of biodegradable materials in surgical procedures has been the subject of studies and exploration to investigate their effects on patient healing. One example is the use of biological meshes in abdominal surgeries, which has been shown to reduce postoperative incisional hernias. Therefore, the use of biological meshes to close contaminated wounds is safe and capable of preventing complications, such as hernias (BHANGU et al., 2020).

Various materials such as hydrogels, polyurethanes, epoxy resins and biodegradable polymers (such as polylactic-glycolic, a copolymer of polylactic acid and polyglycolic acid, polycaprolactone, silk fibroin, rice paper, poly-1,8-octanediol -co-citrate and the role of cellulose nanofibrils), have been used to promote healing. These materials function as mechanical barriers and have greater hydrophobicity, resistance and conductivity compared to synthetic materials (LI et al., 2018; PATHAN; SHENDE, 2021).

Furthermore, the use of biodegradable materials in healing has shown to be a promising approach to improve the results of this crucial process in the recovery of damaged tissues. The effectiveness of dressings is related to the promotion of cell migration, neovascularization and re-epithelialization. In this sense, silk-based dressings have been extensively studied and stand out for their excellent biocompatibility and wound healing properties, outperforming conventional dressings. In addition, these dressings have low toxicity, which makes them even more advantageous to promote effective and safe healing (KAMALATHEVAN et al., 2018; LEE; KANG, 2021).

Silk is composed of two fundamental proteins: fibroin, responsible for its fibrous structure, and sericin, a glue-like coating. This combination gives silk unique properties, such as resistance and flexibility. Silk fibroin has several advantages in wound healing. Its excellent mechanical strength provides effective structural support during the healing process. In addition, fibroin is biodegradable, allowing a controlled and gradual degradation that accompanies tissue regeneration. The high porosity of silk fibroin, when used in dressings, facilitates gas exchange and nutrient flow, promoting a favorable environment for healing. Silk sericin also offers significant benefits. It improves cell fixation and growth in the wound area, in addition to stimulating cell proliferation, contributing to the rapid regeneration of damaged tissue. Its antioxidant action contributes to the reduction of oxidative stress, accelerating the healing process. Like fibroin, sericin has low immunogenicity, minimizing adverse reactions by the immune system. In addition, sericin has moisturizing properties, which contribute to the maintenance of a moist environment favorable to wound healing (KAMALATHEVAN et al., 2018; SUN et al., 2023).

Thus, the effectiveness of biodegradable materials in the healing process is evident, due to their different properties. Among them, resistance, elasticity, hydrophobicity, conductivity and biocompatibility stand out (LI et al., 2018) (PATHAN; SHENDE, 2021; KAMLATHEVAN et al., 2018; LEE; KANG, 2021; SUN et al. al., 2023). Analysis of the effects of these materials on healing demonstrates improvements in healing strength, reduction of hypertrophic scars, and improved scar esthetics. In addition, its use has proven to be safe, with the ability to prevent complications, such as incisional hernias, in surgical procedures (BHANGU et al., 2020).

LIMITATIONS AND CHALLENGES

There are several factors that interfere with the success of the healing process of a suture. These factors are related to the patient's characteristics and the inherent characteristics of the surgical procedure. In this sense, the main complications of an operative wound include infection, dehiscence and formation of keloids or hypertrophic scars. These complications may be favored by several factors, such as the patient's age, presence of underlying diseases (such as diabetes), malnutrition, low serum albumin levels, steroid use, immune status, obesity, smoking and wound location. In addition, factors related to the surgical procedure, such as the type and complexity of the surgery, its duration and the type of approach used, also play an important role (MENG et al., 2020).

The development of new therapeutic materials for wound and tissue repair presents the challenge of controlling the complex and dynamic healing process, which involves several biological cascade reactions. Therefore, choosing the appropriate biodegradable material can have specific advantages and disadvantages at each stage of healing. These advantages and disadvantages depend on the form of administration and release of therapeutic factors, which can occur by diffusion, degradation, chemical affinity, influence of pH, size of molecules, as well as trigger factors that impact the action of these biodegradable materials (NIE et al, 2023).

Among the biodegradable materials of different origins, bioactive materials have been widely studied. These materials have favorable characteristics for the healing process, such as immunomodulatory, angiogenic and antimicrobial properties, in addition to favoring cell proliferation. They impact the inflammatory and remodeling phases of healing, modulating signaling pathways and promoting the growth, differentiation and functioning of essential cells in this process. Some examples of widely used bioactive materials are cellulose, collagen, chitosan, alginate and hyaluronic acid, each with its particularities and specific purposes, aiming to meet the requirements and types of each wound (YU; WEI, 2021).

Finally, it is important to emphasize that the primary outcomes of a surgical wound, such as infections and dehiscence, have a direct impact on the postoperative length of stay, hospital readmission rates due to wound complications and the occurrence of adverse events, in addition to the patient satisfaction with the aesthetic result. Therefore, ensuring better outcomes in healing processes through the use of biodegradable materials can reduce costs related to services used in patient care (MENG et al., 2020).

FINAL CONSIDERATIONS

The use of smart sutures with sensors and biodegradable materials promotes efficient healing with greater postoperative safety. Much research has been done on smart sutures using biodegradable materials, however, no single material can suit all surgical applications. It is important to understand that the choice of biodegradable material can have specific advantages and disadvantages in each healing phase. Therefore, it is necessary to develop more research that seeks to identify the most appropriate material to be used, in order to avoid complications in the surgical suture during the postoperative period.

REFERENCES

BHANGU, A. et al. Prophylactic biological mesh reinforcement versus standard closure of stoma site (ROCSS): a multicentre, randomised controlled trial. **The Lancet**, v. 395, n. 10222, p. 417-426, 2020.

KAMALATHEVAN, P. et al. Silk-Based Biomaterials in Cutaneous Wound Healing: A Systematic Review. **Advances in skin & Wound care**, v. 31, n. 12, p. 565-573, 2018.

KHALID, A. et al. Electrospun nanodiamond–silk fibroin membranes: a multifunctional platform for biosensing and wound-healing applications. **ACS applied materials & interfaces**, v. 12, n. 43, p. 48408-48419, 2020.

LEE, J.; KANG, S. K. Principles for Controlling the Shape Recovery and Degradation Behavior of Biodegradable Shape-Memory Polymers in Biomedical Applications. **Micromachines**, v. 12, n. 7, p. 757, 2021.

LI, R. et al. Recent progress on biodegradable materials and transient electronics. **Bioactive materials**, v. 3, n. 3, p. 322-333, 2018.

MENG, L. et al; Multifunctional tissue-adhesive cryogel wound dressing for rapid nonpressing surface hemorrhage and wound repair. **ACS Applied Materials & Interface**, v.12, n.32, p.35856-35872, 2020.

NIE, L. et al. Fabrication and desired properties of conductive hydrogel dressings for wound healing. **RSC advances**, v. 13, n. 13, p. 8502-8522, 2023.

PATHAN, N.; SHENDE, P. Strategic conceptualization and potential of self-healing polymers in biomedical field. **Materials Science and Engineering: C**, v. 125, p. 112099, 2021

PHAN, P.T. et al. Smart surgical sutures using soft artificial muscles. **Scientific reports**, v. 11, n. 1, p. 22420, 2021.

SUN, S. et al. Biodegradable smart materials with self-healing and shape memory function for wound healing. **RSC Advances**, v. 13, n. 5, p. 3155-3163, 2023.

YU, L.; WEI, M. Biomineralization of collagen-based materials for hard tissue repair. **International journal of molecular sciences**, v. 22, n. 2, p. 944, 2021.