

Emerging Trends And Innovations In Oral Surgical Sutures

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Abstract: While surgical sutures remain a cornerstone of wound closure, their evolution has transformed them into sophisticated tools that enhance healing, reduce complications and improve patient outcomes. This review synthesizes recent breakthroughs in suture technology, focusing on antimicrobial-impregnated, drug-eluting, shape-memory, plant-based, electronic, and stem cell-infused sutures, alongside new advancements in surgical staples, Steri Strips, and tissue glue. Innovations such as triclosan-impregnated sutures and silver nanoparticles mitigate infection risks, while shape-memory polymers enable self-tightening knots, and stem-cell-infused sutures promote tissue regeneration. Electronic sutures monitor real-time wound status, and biodegradable plant-based materials offer eco-friendly alternatives. Clinical applications in oral, orthopedic, and cardiovascular surgeries highlight reduced surgical site infections, accelerated healing and minimal scarring. Challenges include cost, regulatory hurdles and scalability, but the trend toward patient-centric, multifunctional designs promises equitable and precision medicine. This review underscores suture's shift from passive closure to therapeutic, adaptive solutions, heralding a future of smarter, greener surgical care.

Keywords- Suture, innovations, technology, advancements

INTRODUCTION

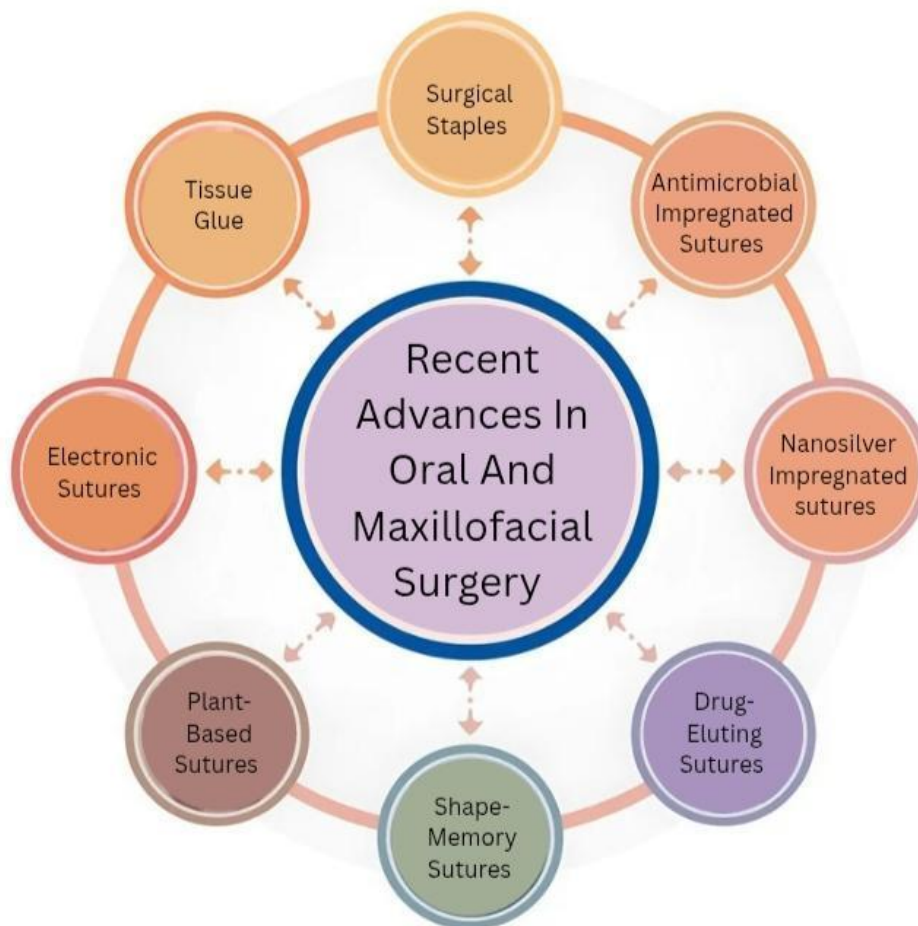
Sutures are biomedical devices composed of fibres that facilitate wound closure, haemostasis and healing by holding surrounding tissues together and sealing surgical sites with the primary purpose of supporting the healing process and promoting closure of trauma-induced and surgical wounds.

Sutures can be broadly classified into two categories based on their biodegradability: absorbable and non-absorbable. US Pharmacopeia has defined absorbable sutures as biomaterials that lose most of their tensile strength within 60 days post-implantation in vivo.¹ These sutures are further categorised into natural and synthetic materials. Natural absorbable sutures, such as catgut, are derived from animal tissues and contain collagen,² while synthetic absorbable sutures, such as polyglycolic acid(PGA), are manufactured to provide higher tensile strength and controlled degradation.³

Non-biodegradable sutures, on the other hand, do not degrade and must be removed post-healing. These sutures can also be natural or synthetic, with examples including silk and nylon.² Silk sutures possess excellent handling and knot-tying properties but exhibit high tissue reactivity, making them suitable for specific procedures such as cardiovascular, ophthalmic, and neurological surgeries.⁴ Nylon sutures, a synthetic polyamide, have a notable drawback of "memory," which can affect their handling.^{1,5}

An ideal suture material should possess a combination of desirable characteristics, including good handling properties, excellent traction, non-capillary action, hypoallergenic and non-carcinogenic properties, ease of sterilization without compromising its properties, and cost-effectiveness, making it a versatile solution for various surgical and medical applications.⁶

In oral surgery, sutures are critical for achieving wound closure, hemostasis and promote tissue healing. The choice of suture material depends on factors such as tissue layers, edema, suture removal time, strength, and inflammatory response.⁷ Although traditional sutures remain widely used due to their effectiveness and availability, advancements have led to improved materials, aiming to enhance performance, reduce complications and optimise patient outcomes. Recent breakthroughs have led to innovation of sutures-including antimicrobial impregnated sutures, silver-nano particle suture, drug-eluting, shape-memory, plant-based and electronic sutures as well as stem-cell infused sutures, Steri strips and tissue glue that are redefining surgical care and shaping the future of medicine.



SURGICAL STAPLES

Surgical staples are a valuable tool in oral and maxillofacial surgery (OMFS), offering faster wound closure, reduced tissue trauma and lower infection risk compared to traditional sutures. They are commonly used for external skin incisions (e.g., facial trauma, tumor removal, orthognathic surgeries) and intraoral mucosal closures (e.g., grafts, extractions) using absorbable staples. The key advantages include 2–3x quicker application and minimal tissue handling, making them ideal for high-volume or complex cases. However, they are costlier, require removal (for metal staples), and carry a scarring risk if not placed precisely. They're less suitable for high-tension areas or near vital structures.⁸

Recent advancements are enhancing their utility: 3D printing and virtual planning enable custom titanium meshes and robotic-assisted precision, while biodegradable staples (lactomer, PGA) eliminate the need for removal. Studies show faster closure with staples (4.02 cm/min vs. 1.25 cm/min with sutures) but more pain during removal.⁹

ANTIMICROBIAL IMPREGNATED SUTURES

Antimicrobial-impregnated sutures are designed to prevent surgical site infections (SSIs) by releasing antimicrobial agents that inhibit bacterial growth.¹⁰ These sutures promote healing and prevent postoperative infections making them a valuable tool in various surgical specialties including oral and maxillofacial surgery, orthopaedic surgery, general surgery, and cardiovascular surgery. Consequently improving patient outcomes and reducing healthcare costs.⁷

These sutures exhibit the slow release of antimicrobial agents from the suture surface, providing a sustained antimicrobial effect that prevents bacterial adhesion and colonization.

The use of antimicrobial impregnated sutures has been shown to be effective in reducing the incidence of SSIs—a major complication of surgical procedures which is linked to prolonged hospital stays,¹ increased healthcare costs and even mortality. Examples of antimicrobial sutures include Vicryl Plus, Monocryl Plus, PDS Plus, Biosyn, and Chlorhexidine-coated sutures, which utilize agents like triclosan¹¹, chlorhexidine², and chitosan¹². These agents have broad-spectrum antimicrobial activity, effective against a wide range of microorganisms, including bacteria, fungi, and viruses.

NANO-SILVER IMPREGNATED SUTURES

Silver nanoparticle-treated sutures are a promising innovation for preventing surgical site infections. Silver nanoparticles (AgNPs) are considered ideal candidates for coating polymeric medical devices, including sutures, due to their potent antimicrobial properties. The mechanism of action involves the formation of reactive oxygen species, which damage microbial DNA and cell membranes, ultimately leading to cell death.^{7,13}

The use of AgNPs reduces the required amount of antibiotics and nanoparticles needed for effective antibacterial impact, minimizing potential adverse effects. Their small size (less than 100nm) and high surface-to-volume ratio enable greater interaction with microbial membranes, enhancing antimicrobial activity. AgNPs have been applied in various biomedical applications, including guided tissue regrowth, tooth extractions, and implant dentistry.¹³

In wound closure, AgNPs facilitate healing by promoting collagen accumulation and tissue repair. They are used in medical devices such as urinary catheters and wound dressings for burns. Recently, AgNP-treated sutures have gained interest for preventing bacterial adhesion and promoting aseptic wound closure. A long-term antimicrobial coating developed with AgNPs and hyperbranched polylysine has shown efficacy in reducing bacterial adhesion without toxicity to fibroblast cells.⁷

AgNPs have potential applications in oral and maxillofacial surgery, including mouth cancer treatment, apical operations (involving apex of the tooth's root), and bone wound recovery. Their versatility and efficacy make them an attractive option for improving surgical outcomes and reducing infection risk.¹⁴

DRUG-ELUTING SUTURES

Drug-eluting sutures represent a revolutionary innovation in surgical care, merging the mechanical function of traditional sutures with localized drug delivery capabilities. These sutures are designed to release therapeutic agents-antimicrobials, anti-inflammatory agents, analgesics, and growth factors, directly at the wound site, maintaining therapeutic concentrations without systemic toxicity.^{15,16}

These sutures are prepared by incorporating active pharmaceutical ingredients into biodegradable suture materials via coating, impregnation or integration. It offers a controlled release of drugs, minimizing systemic side effects and reducing surgical site infections^{7,16} making them ideal for various surgical specialties, including maxillofacial surgery, orthopedic surgery, cardiovascular surgery, general surgery and regenerative medicine applications.

The key attributes of drug-eluting sutures include reduced systemic toxicity and enhanced wound healing. They also offer potential for combination drug therapy and improved mechanical properties due to drug-polymer integration, making them suitable for invasive surgeries and tissue engineering. By providing targeted therapy directly at the injury site, drug-eluting sutures represent a significant advancement in surgical care, improving patient outcomes and revolutionizing the future of medicine.^{15,17}

SHAPE MEMORY SUTURES

Shape memory sutures are an advanced surgical tool, made from "smart" shape memory polymers (SMPs) that change shape in response to external stimuli like temperature, electronic/magnetic fields, or moisture. These sutures are designed to be biocompatible, breaking down or being absorbed by the body over time and are made from materials like shape-memory assisted self-healing polyurethane.

These sutures are programmed with a permanent shape, such as a tight knot, and then deformed into a temporary shape, like a straightened form, at a lower temperature.¹⁸ During deployment, the sutures are placed in the tissue in their temporary state and upon exposure to body temperature or another stimulus, they shift back to their permanent shape, providing the desired mechanical action such as tightening a knot securely.¹⁹

This unique property makes them particularly useful in oral surgery for closing incisions or wounds where achieving optimal tension with conventional sutures can be challenging.

The use of shape memory sutures offers several advantages, including minimally invasive placement, self-securing knots, and potential self-healing properties.²⁰ With ongoing research and development, shape memory sutures are poised to enhance surgical outcomes and improve patient care.²¹

PLANT-BASED SUTURES

Plant-based sutures are derived from plants like Ramie (*Boehmeria nivea*), hemp, cotton, alginate and bamboo which are rich in cellulose and other fibrous components. These sutures are designed to be either absorbable (degradable) or non-absorbable, depending on treatment. The manufacturing process involves harvesting the plant, extracting fibers through retting or mechanical processes, treating the fibers to remove impurities, and spinning them into threads of desired diameter.

The resulting sutures possess desirable properties including high tensile strength, antimicrobial activity and biocompatibility, making them suitable for surgical use. Ramie plant-based sutures offer high tensile strength, antimicrobial properties, and affordability with the added benefit of promoting scar-free healing.²²

These sutures are used in oral surgery for wound closure in dental procedures where minimal tissue reaction is required and can aid in post-operative healing with reduced scarring.

The plant-based sutures are sterilized and may be coated with antimicrobial agents to enhance their properties and provide a promising alternative to traditional sutures offering effective wound closure and healing with minimal complications.²³

ELECTRONIC SUTURES

Electronic sutures are innovative medical devices that integrate electronic components into traditional sutures enabling real-time monitoring and activation of biological responses to improve tissue health. These smart sutures are designed with a flexible, snake-like shape and incorporate sensors, microheaters and other components to facilitate monitoring and therapy.⁷

The composition of electronic sutures includes silicon and platinum nanofilm temperature sensors, gold microheaters for localized heating and flexible substrates that can withstand surgical procedures. They are designed to detect changes in wound conditions such as infection via temperature changes and aid in maintaining optimal conditions for tissue repair.⁷

In oral surgery, they may be used for post-operative monitoring, infection detection, and targeted therapy. Electronic sutures offer several special features including temperature sensing, microheating, flexibility, durability, and integration capabilities with other functionalities like drug release or biosensing.²⁴ With their advanced design and capabilities, electronic sutures have the potential to revolutionize wound monitoring and treatment particularly in delicate oral tissues where bacterial load is high. Ongoing research and development are expected to expand their applications in various surgical specialties.

STEM CELL INFUSED SUTURES

Stem cell infused sutures are biological sutures loaded with living stem cells, typically mesenchymal stem cells (MSCs) or adipose-derived stem cells (ASCs), which provide a dual role: mechanically closing a wound and delivering therapeutic cells to boost tissue repair.²⁵ The preparation involves coating or impregnating a biodegradable suture base, such as polyglycolic acid or collagen, with a suspension of stem cells.²⁶ The cell-seeded sutures may be cultured to allow cell adherence and proliferation, and can be cryopreserved for storage.²⁷

In general surgery, they are used in cardiac surgery, tracheal anastomosis, colonic anastomosis and wound healing, improving cell retention, reducing inflammation and promoting collagen deposition.²⁸

In dentistry, stem cell-infused sutures are being explored for oral maxillofacial uses, including post-extraction sockets, periodontal surgery, soft tissue repair, and implantology, due to their regenerative potential.²⁹ They aid socket preservation, promote bone regeneration, and enhance healing of gingival flaps or mucosal wounds.

The use of stem cell seeded sutures has shown promising results including improved osseointegration, reduced fibrosis and enhanced wound healing.³⁰ Recent advances include the use of quantum dot nanoparticles to track seeded cells in vivo and ASC-loaded biodegradable sutures that release cytokines to aid wound healing.³¹

STERI STRIPS

Steri strips are porous, sterile surgical tape strips used for closing small wounds, applied over a clean wound to grip the skin and pull the edges together, promoting healing.⁷ They serve as an alternative to sutures or staples for minor lacerations, cuts, or low-tension surgical incisions. They allow airflow to the wound, minimising skin maceration, scarring and infection risk. Steri strips offer advantages like being less traumatic than stitches, easy removal, and suitable for patients with suture sensitivity.³²

Steri strips are applied on clean and dry skin surrounding the wound, in a perpendicular direction gently pulling the skin together. Multiple strips may be used depending on size. In oral surgery, they're used for post-extraction or minor procedures, gingival grafts, or biopsies, holding tissue in place temporarily.³³ Recent advances include antimicrobial-coated strips with agents like chlorhexidine, bioabsorbable variants that dissolve eliminating need, and enhanced adhesives that stick better on moist skin surfaces, making them useful in challenging cases.

TISSUE GLUE

Tissue glue, also known as liquid stitches or liquid suture are cyanoacrylate-based fast adhesives used to close small to large wounds, incisions and cuts, particularly on areas like the face or groin composed from cyanoacrylates, such as methyl-2-cyanoacrylate or ethyl-2-cyanoacrylate. Modern formulas like 2-octal cyanoacrylate (e.g., Liquiband, Dermabond, Surgiseal) offer flexibility, strong bonding, and easy application.⁷

In oral surgery, they're used for soft tissue repairs, sealing lacerations, post-extraction sites and periodontal uses like flap closure or graft stabilization.³⁴ Some experimental adhesives incorporate cyanoacrylates for temporary or adjunct bonding. Recent advances include long-chain cyanoacrylates with better flexibility and less irritation and antibacterial-infused formulations with microbial agents to reduce infection risk, making them a reliable option for wound closure.³⁵

CONCLUSION

The future of sutures is revolutionising surgical care by delivering advanced, multifunctional solutions that boost healing, reduce complications and improve patient outcomes. Breakthroughs such as surgical staples, antimicrobial sutures, drug-eluting sutures, shape-memory materials, plant-based biodegradables, electronic sensors, and stem-cell infused biosutures are redefining surgical precision across specialities including oral, orthopedic, and cardiovascular surgery-by tackling key challenges like infection risk, scarring and tissue regeneration.

Advanced sutures are becoming smarter, greener, and more patient centric- using affordable options like plant-based biodegradable sutures, antimicrobial coatings and drug-eluting systems to cut infection risks, minimizing scarring and accelerating recovery. Integrated with stem cells, electronic monitoring and smart materials, they lower pain, complications and healthcare costs ultimately evolving into a therapeutic tool that heals smarter, gentler and faster, shortening recovery times.

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