

Review Article

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Fastening the Future: Surgical Zip Ties for Enhanced Wound Closure and Patient Well-Being

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ABSTRACT

Surgical zip tie skin closures are emerging as a revolutionary approach in wound management, promising significant advancements in patient safety and surgical success. Current research emphasizes the efficacy of zip tie closures in promoting wound healing, reducing the risk of dehiscence, and enhancing cosmetic outcomes across various surgical procedures. Compared to traditional suturing techniques, zip tie closures offer secure wound approximation, minimize tension on wound edges, and contribute to faster recovery times with lower incidences of infection and scarring. Case studies and clinical trials demonstrate the effectiveness of these closures, emphasizing their role in improving surgical outcomes. Future investigations should focus on optimizing zip tie design and material properties to ensure compatibility with different skin types and surgical sites. Innovations in biodegradable and antimicrobial materials could further enhance the utility and applications of zip ties. The potential for using zip tie closures in minimally invasive and robotic-assisted surgeries offers precision and ease of use in complex procedures. Multidisciplinary collaboration between surgeons, engineers, and biomaterial scientists is essential for refining zip tie closure systems, conducting clinical trials, and establishing standardized protocols for integration into routine surgical practice. Addressing challenges related to material biocompatibility, mechanical strength, and user ergonomics will be essential for navigating challenges and limitations. Ultimately, the adoption of surgical zip tie skin closures has the potential to revolutionize wound management and improve patient care, setting new standards in surgical care through innovation and evidence-based practice.

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Introduction

Surgical zip tie skin closures, also known as zipper devices or zip sutures, are emerging as a novel approach in wound management promising significant advancements in patient safety and surgical success. These devices are applied directly over intact skin on each side of the wound edges without the need for anchoring into the skin or subcutaneous plane, making them less painful and time-consuming compared to traditional methods like sutures and staples. Traditional sutures, while effective, require more time and surgical skill to implement, while surgical staples, though expedient, can result in increased tissue trauma, suboptimal wound approximation, limited range of motion, and increased patient pain [1]. Surgical zip ties offer a hybrid solution, combining the time efficiency benefit of staples with the precision and reduced tissue damage associated with sutures. Currently, surgical zip ties are employed in various clinical scenarios, including the closure of

surgical incisions and the management of traumatic lacerations in emergency settings. These devices operate through the use of interlocking polymer strips that are applied to either side of the wound [2]. Following application, the strips are tightened to approximate the wound margins. The closure along the wound is adjustable and site specific, which allows for appropriate tension throughout the wound and provides a customizable closure based on shape, location, and the patient's skin. This mechanism also minimizes the need for percutaneous needle penetration, reducing the potential for needle-stick injuries and reducing scar formation.

Zip tie closure devices appear to offer several advantages over traditional suturing methods, including reduced closure time, lower infection rates, better healing, and higher patient satisfaction, making it a promising alternative to traditional sutures and wound closure methods. Studies have shown that zipper devices significantly reduce wound closure time by as much as 4.9 minutes compared to traditional sutures [3,4]. Additionally, zip tie closure devices are associated with lower surgical site infection (SSI) rates

and better scar outcomes, making them advantageous for both anti-infection and scar formation [4]. Moreover, the effectiveness of zipper devices in minimizing complications such as infection, dehiscence, and incisional hernia has been supported, although further research is needed to fully understand their mechanisms of action [5]. Despite these benefits, institutional costs and provider familiarity with zipper devices compared to traditional methods should be considered. The potential of minimizing postoperative complications and improving patient outcomes by employing zip tie skin closure devices must also be considered in this cost-benefit analysis.

Advancing patient safety and surgical success with surgical zip tie skin closures is crucial due to their numerous benefits compared to traditional methods. Zipper devices provide a less technically demanding and more efficient method for wound closure, holding the potential to significantly aid practices with limited surgical expertise and resources. This review comprehensively examines the benefits of zip tie closures, highlighting the value of precise wound closure, reduced tissue trauma, and enhanced cosmetic outcomes. Through an in-depth analysis of case studies and clinical trials, the review demonstrates the effectiveness of these closures in surgical procedures, underscoring their potential to significantly improve surgical outcomes. Additionally, the review examines the specific mechanisms by which zip tie closures enhance wound healing and minimize complications. It investigates the design features that make these closures superior to traditional methods, such as their ability to evenly distribute tension along the wound edges, which reduces the risk of tissue necrosis and dehiscence. This review also explores patient perspectives, noting increased satisfaction due to faster recovery times, lower infection rates, and improved scar formation. By providing a detailed overview of existing studies and clinical applications, this literature analysis aims to establish a solid evidence base for the broader adoption of surgical zip tie closures. Zip ties have transformative potential in surgical practice and are on their way to becoming a standard technique in wound management, particularly for procedures requiring meticulous closure and optimal healing outcomes.

Current Investigations

Proposing the implementation of new devices such as surgical zip ties to replace traditional methods (e.g., sutures, staples) requires careful consideration and evaluation. It is imperative that the new device meet or exceed the current standards set by conventional wound closure techniques. Zip tie closures must demonstrate efficacy in promoting wound healing by securing wound approximation, minimizing tension on wound edges, and reducing the risk of dehiscence and infection. Additionally, devices should offer greater efficiency for the provider, reduce postoperative complications, contribute to faster recovery times, and enhance outcomes across various surgical procedures, ultimately leading to improved patient satisfaction. Together, these factors collectively encompass the critical criteria that any new wound closure device must fulfill to be considered a viable alternative to traditional methods and are important components of wound management, surgical site healing, and patient outcomes.

Wound Approximation

Wound approximation is a critical aspect of surgical and medical care, primarily aimed at ensuring secure tissue healing. The process of approximating wound edges is essential for minimizing complications and promoting efficient healing. A well-approximated wound reduces tissue tension, which is necessary for preventing dehiscence and ensuring that the wound heals properly without excessive scarring. Furthermore, the overall success of

wound approximation is influenced by both systemic and local factors, including the patient's nutritional status, blood supply, and the minimization of distracting forces on the wound edges [6,7]. Wound approximation not only plays a pivotal role in the physical healing process but also significantly impacts the aesthetic outcome, which is often a measure of patient satisfaction with the procedure. Wound approximation using traditional suturing methods requires technical skill, time, and as with all surgical interventions carries a risk of complications, such as infection and dehiscence. Careful alignment not only accelerates healing but also supports functional recovery, particularly in areas subjected to movement or stress. Overall, effective wound approximation is essential for achieving optimal surgical results and ensuring an uneventful recovery.

In this context, surgical zip ties have emerged as a promising alternative to traditional methods. These devices offer numerous advantages over conventional sutures, enhancing both the effectiveness and ease of wound closure. For example, the medical zip fastener developed by Li Yibiao and Pan Meiling combines non-woven fabrics with polyethylene foaming layers to achieve a secure, minimally scarring closure, which reduces patient discomfort and postoperative complications [8]. Additionally, the double or triple zip-tied anastomosis method by Francisco Sergio Pinheiro Regadas demonstrates how zip ties effectively rejoin tubular organs, creating a smooth interface that minimizes the risk of leakage or infection [9]. Furthermore, the low elasticity and compression-proofed design of zip ties enhances wound stability by maintaining resistance against cross tension. Advancements in zip tie technology highlight how surgical zip ties can improve wound management by addressing many of the challenges associated with traditional suturing methods, ultimately leading to better surgical outcomes.

Tension on Wound Edges

Tension on wound edges significantly impacts the healing process and the formation of scars. High tension at wound edges can lead to wound dehiscence and poor healing outcomes, as the tension disrupts the natural healing process and increases the likelihood of hypertrophic scar formation [10]. Various strategies have been developed to mitigate this issue. For instance, the use of tension-shielding hydrogel systems, such as the HTA hydrogel, has shown promise in reducing wound tension, promoting scarless healing, and providing additional benefits like photothermal antibacterial properties and self-healing capabilities [11]. Tension offloading devices, when applied pre-operatively, have been found to significantly improve skin elasticity, reduce scar width, and accelerate the wound healing process, with better outcomes observed when used both pre- and post-operatively [12]. These studies stress the role of tension, and more specifically tension reduction, in optimizing wound recovery, healing, and scar formation. This magnifies the direct relationship between mechanical forces and biochemical processes that take place during the healing process. Not only does tension on wound edges directly influence the healing process, but it also impacts patient pain during recovery. The invention of tension offloading devices has significantly improved surgical and wound management techniques and improved patient recovery.

Surgical zip ties have shown significant promise in minimizing tension on wound edges, enhancing wound healing and patient comfort. Tension offloading devices work in conjunction with traditional management and closure of wounds, while surgical zip ties are able to stand alone as both the primary closure method and tension offloading device. This dual functionality simplifies the

closure process and ensures consistent tension distribution across the wound. The double or triple zip-tied anastomosis method outlined before ensures a smooth interface and reduces tension at the rejoined sections, which is imperative for optimal healing [9]. By maintaining a consistent and gentle approximation of wound edges, zip ties mitigate the risk of complications such as dehiscence and infection, which are often associated with excessive tension. A meta-analysis comparing zipper devices to traditional sutures found that zipper devices not only achieved a lower rate of surgical site infections but also resulted in shorter wound closure times and better scar scores, indicating their superiority in minimizing tension and enhancing overall wound healing [4]. These outcomes highlight the superiority of zip ties in minimizing tension and promoting wound healing compared to conventional suturing techniques. Collectively, these findings from recent studies illustrate that surgical zip ties are effective in minimizing tension on wound edges, thereby improving healing outcomes. The design of surgical zip ties incorporates features that enhance their effectiveness, such as adjustable tension settings and secure locking mechanisms. These design elements contribute to their ease of use and heightened performance, making them a valuable tool in modern wound management. By integrating these devices into surgical practice, healthcare providers can achieve more reliable wound closures, reduce postoperative complications, and improve patient satisfaction with both functional and visual outcomes.

Dehiscence

Dehiscence involves the partial or complete separation of wound edges, which compromises the integrity of the surgical repair and leads to increased risk of infection, delayed healing, and adverse outcomes. This complication often results from excessive tension on wound edges, inadequate wound closure, or mechanical stress. Dehiscence can also cause prolonged recovery times and increased patient discomfort, as well as the need for additional surgical interventions to correct the issue. One of the leading causes of dehiscences remains suture-driven surgical site infections and necrosis [13]. Due to sutures being composed of a foreign material embedded in live but compromised tissue, bacteria thrive on suture surfaces and can even form biofilms making them incredibly resistant to antibiotics. These serious infections lead to prolonged hospital stays and increased morbidity and mortality. Antimicrobial sutures have been proposed and at times utilized; however, even these sutures can be compromised with the rise of antibiotic resistance. Effective strategies to prevent infections and subsequent dehiscence are crucial to ensure optimal wound healing and minimize postoperative complications.

Surgical zip ties have also shown promise in reducing the risk of dehiscence compared to traditional methods, particularly in challenging wound scenarios. One of the primary advantages of using zipper devices over traditional sutures is their non-invasive nature, which significantly reduces the risk of infection. Unlike traditional sutures, which involve puncturing the skin multiple times, zip ties can be applied with a single, continuous mechanism that avoids additional trauma to the tissue. This reduced invasiveness significantly lowers the likelihood of infection, as there are fewer entry points for bacterial pathogens. Additionally, there is a lack of foreign body surface on which to proliferate. By avoiding the repeated needle passes required for suturing, zip ties reduce the risk of pressure necrosis, a condition where excessive pressure from sutures can compromise blood flow to the surrounding tissue, impair healing, and cause dehiscence [14]. Overall, the integration of surgical zip ties into wound

management practices potentiates a significant advancement in reducing dehiscence. Further research and clinical trials are needed to investigate the prevalence of dehiscence using zip ties compared to traditional closure methods.

Bacterial Infection

Bacterial infection remains a significant complication in wound closure, posing serious risks to patient recovery and outcomes. Mitigating bacterial infections through innovative surgical techniques, medical devices, and wound closure methods remains an ever-evolving area of surgical research. In emergent colorectal surgery, complete skin closure correlated with the lowest rate of surgical site infection and mortality, stressing the importance of wound approximation [15]. In cardiac implantable electronic device explants, primary wound closure was associated with shorter hospital stays and a reduced likelihood of postoperative hematoma compared to secondary wound closure or open wound management [16]. Additionally, the use of knotless barbed sutures and self-adhering mesh with polymeric glue in multilevel or revisional posterior spinal surgery significantly shortened wound closure time without increasing surgical complications, demonstrating the efficacy of advanced closure techniques in reducing infection risks and improving surgical efficiency [17]. Many recent examples demonstrate the importance of ongoing research and development in surgical closure techniques. Collectively, these findings highlight the critical role of selecting appropriate wound closure techniques and products that prioritize wound approximation and rapid wound healing.

Surgical zip ties have shown promise in both minimizing bacterial infection compared to suture methods and establishing lower rates of surgical site infections with a relative risk reduction of 0.63 [4]. In scenarios simulating real-world conditions with patient-induced movement, zipper devices have outperformed sutures in maintaining wound integrity and minimizing bacterial penetration, which is imperative for preventing infections during the healing process [18]. Another study by Greenbaum et al. demonstrated that the overall complication rates, including infection and wound dehiscence, are comparable between zipper devices and traditional suturing methods [19]. These findings collectively highlight the advantages of zipper devices in enhancing wound healing. Through offering evidence of improved infection control, zipper devices present a compelling alternative to traditional sutures, particularly in settings necessitating a need to minimize postoperative complications.

Efficiency and Training

Efficient closure in surgical procedures is vital for several reasons, with an emphasis on patient safety, healing, and overall surgical success. In the context of complicated intra-abdominal infections, efficient closure strategies play a significant role in reducing mortality and morbidity by decreasing proinflammatory cytokines, bacterial count, and improving fluid management and monitoring [20]. Time spent closing directly impacts patient outcomes by reducing the time under anesthesia, thereby minimizing the associated risks and potential complications. Faster procedures also translate to less operative trauma and quicker recovery times. Moreover, efficient closure time optimizes the use of operating room time and resources, allowing healthcare facilities to treat more patients and reduce wait times. This is particularly important in high-demand settings where resource management is constantly critiqued and evaluated. Streamlined procedures can also lower healthcare costs by reducing the length of hospital stays and the need for postoperative care, making efficient surgical methods

beneficial for both patients and healthcare systems.

Surgical zip ties have shown to be significantly more efficient than traditional sutures for wound closure. The zipper device is less technically demanding and time-consuming, reducing skin closure time by approximately 4.9 minutes compared to sutures [3]. Unlike traditional sutures that necessitate multiple passes through the tissue, surgical zip ties provide a single, secure closure, which not only speeds up the procedure but also reduces the risk of errors. Surgical zip ties, such as the Medizip and ZipFix systems, have been shown to offer several advantages in terms of recovery time and overall patient outcomes. Studies indicate that these systems significantly reduce the time required for wound closure compared to traditional methods. For instance, the Medizip system reduced the average wound closure time to 2 minutes compared to 9.4 minutes with intracutaneous sutures, and patients reported positive assessments of wound healing and scar formation [21]. Similarly, another study found that the Medizip system required an average of 2.3 minutes for skin closure, with high ratings for ease of handling and patient comfort [22]. In cardiac surgery, the ZipFix system demonstrated a reduction in overall operation time by 11 minutes compared to conventional wire closures, with no significant difference in infection rates or postoperative complications [23]. The technical demands of suturing require a high level of skill and precision, and inadequate technique can compromise wound closure and increase dehiscence risk. Suture placement and removal can also be time-consuming, adding to the duration of surgical procedures and the overall management of wounds. Surgical zip ties are easy to apply and remove, decreasing the overall time spent on wound management and reducing the burden on surgical staff.

Patient Experience and Scar Formation Outcomes

Sutures, while effective for wound closure, can be uncomfortable for patients and often come with postoperative complications and suboptimal scar formation. The process of puncturing the skin multiple times to place sutures can cause significant pain and discomfort, both during and after the procedure. As the wound heals, the sutures can create localized tension and irritation, sometimes leading to inflammation or swelling around the suture sites [24]. Patients may also experience itching or a pulling sensation as the wound heals and the skin tightens, particularly if they are placed too tightly or if the patient experiences movement in the wound area. Proper care and maintenance of sutured wounds are crucial to prevent complications, necessitating careful monitoring and management by both patients and healthcare providers. Scar formation is an aspect to consider in surgical incision and wound closure, because it directly impacts both the functional and aesthetic outcomes of the procedure. A well-healed scar can restore the integrity and appearance of the skin, whereas poor scar formation can lead to complications such as hypertrophic scars, keloids, and contractures, which can restrict movement and cause discomfort [25]. Aesthetically, prominent or unsightly scars can affect a patient's self-esteem and satisfaction with the surgical results, particularly in visible areas of the body. Minimizing scar formation through effective wound closure techniques is essential for achieving optimal healing and enhancing patient satisfaction.

Surgical zip ties have been shown to provide better patient experience and superior scar outcomes. This superiority stems from the ability of zip ties to distribute tension more evenly along the wound edges, which reduces localized stress and minimizes the risk of tissue damage and scarring. The non-invasive nature of the zipper device contributes to less postoperative discomfort and eliminates the need for suture removal, enhancing patient comfort

and satisfaction [26]. In a randomized controlled trial involving 25 patients undergoing bilateral total knee arthroplasty, the Zip device for skin closure resulted in significantly less pain and better scar appearance compared to staples [27]. Other studies have reiterated these findings, indicating that surgical zip ties resulted in less postoperative pain and better cosmetic outcomes compared to conventional staples used in TKA surgeries, with no significant difference in wound complication rates, suggesting its potential for patients prioritizing comfort and appearance after surgery [2,28]. The zip groups consistently had better Patient and Observer Scar Assessment Scale (POSAS) and Vancouver scar scores for various parameters including color, stiffness, thickness, and overall appearance post-operatively. Multiple benefits have been identified highlighting the importance of considering alternative wound closure methods that both meet medical standards and improve patient satisfaction.

Onuminya et al. used Medizip surgical zippers in Nigeria and reported that 90% of the Medizip group had "good scar outcomes", characterized by thin, linear scars, compared to only 44% in the conventional suture group [29]. This finding was confirmed in a subsequent study, which found that 86% of patients in the surgical zipper group had "good scar outcomes", significantly higher than the 42% in the conventional suture group [30]. The consistent superior results with Medizip suggest that the precision and ease of use associated with these devices contribute to better scar formation and reduced postoperative discomfort. As a result, surgical zip ties are increasingly recognized for their ability to achieve aesthetically pleasing outcomes and support optimal healing, affirming their potential as a valuable alternative to traditional suture methods. The versatility of surgical zip ties also demonstrates significant advantages in diverse medical specialties. Their effectiveness in providing significantly better scar formation in pediatric cardiothoracic surgery underscores their value in more delicate populations, where enhanced comfort and discreet surgical closures are appreciated [31]. The simplicity of use and removal, combined with precise alignment and consistent pressure results in finer, less noticeable scars. Zip tie features contribute to better outcomes, making surgical zip ties an increasingly desirable option in various surgical contexts.

Opportunities for Applications in Advanced Surgical Techniques

Minimally Invasive Surgeries

Minimally invasive surgeries (MIS) benefit significantly from the precision and reduced trauma associated with optimized zip ties. These tools are ideal for contexts where space and visibility are limited, necessitating precise instruments to function effectively. The accuracy of tissue approximation and hemostasis provided by zip ties ensures surgical success. Laparoscopic surgery takes place inside body cavities with limited space for tissue manipulation, requiring tools that can navigate and operate efficiently within these confines. Zip ties, with their precision and reliability, can be invaluable in such operations. Endoscopic surgery often presents an even smaller window for operation. Studies have evaluated suture techniques in laparoscopic and endoscopic settings due to their challenging surgical environments but have not extensively discussed the application of zip ties in these contexts [32,33]. The ability of zip ties to function effectively in restricted spaces can significantly expand their usability and contribute to less invasive surgical approaches. This may include engineering zip ties that are flexible yet strong, capable of navigating tight spaces while maintaining their integrity and functionality. The reduced trauma associated with the use of optimized zip ties allows for less damage to surrounding tissues. Therefore, their use in MIS can promote

shorter hospital stays and faster return to normal activities for patients. By reducing the duration and complexity of surgeries, along with associated healthcare costs, zip ties are able to make advanced surgical techniques more accessible and affordable. As MIS continues to evolve, the integration of sophisticated tools like zip ties will play a pivotal role in enhancing surgical efficiency.

Robotic-Assisted Surgeries

Robotic-assisted surgeries (RAS) represent the frontier of precision and control in surgical practice, and optimized zip ties can significantly enhance these procedures. Zip ties should be designed to integrate seamlessly with robotic systems, allowing for precise manipulation and application under advanced imaging and robotic control. Current investigations in RAS evaluate suture techniques and advocate for identifying optimal suturing methods to enhance the development of RAS procedures, further improving their efficiency and adoption in clinical practice [34]. The application of zip tie sutures in this setting enhances manipulation and facilitates access to challenging anatomical sites through the dexterity and precision of robotic instruments, expanding the scope of procedures that can benefit from zip tie applications. The integration of robotic tools is already pushing the boundaries of what is possible in surgical interventions, making previously inoperable conditions more manageable. Additionally, zip ties designed for robotic use can feature adjustable tension mechanisms and biocompatible materials, enhancing their functionality and safety. By enabling precise control and reducing tissue trauma, the continued development of these tools in conjunction with robotic systems could improve surgical practices, setting new standards for minimally invasive procedures.

Training and Adoption in Surgical Practice

The introduction of optimized zip ties into surgical practice necessitates comprehensive training for surgeons and medical staff to ensure proficiency and safety. Training programs should address the nuances of their application, including troubleshooting common problems and understanding best practices for their use. Hands-on workshops and simulations can aid adoption by familiarizing medical providers with the new tools, helping them become comfortable with their operation. Practical experience is essential to minimize issues, such as the transposition of structures. In Brazil, zip tie sutures were utilized during a patient's initial emergency care to reduce an open mandibular fracture, providing temporary fracture reduction and stabilization. This intervention significantly reduced local pain and distress associated with bone movement [35]. Although the definitive treatment for the injury still required surgical procedures, such as fracture cleaning, reduction, and rigid fixation, zip tie sutures proved to be an effective bridging tool. Given the face's sensitivity, particularly for cosmetic reasons, the application of zip tie sutures in this area holds promise; however, appropriate training is essential to ensure clinicians can avoid mistakes. Integration into existing educational programs for medical residents and fellows can overcome reluctance to change, ensuring new surgeons are well-versed in their use.

Demonstrating clear benefits through clinical studies and testimonials can drive widespread use in hospitals worldwide. Clinical trials and studies showcasing improved patient outcomes, reduced complications, and cost-effectiveness will accelerate acceptance into mainstream practice and facilitate widespread improvements in patient care. Testimonials from surgical leaders who use zip ties can further promote their reputation and acceptance. The success and durability of these zip ties will depend on continuous education, feedback, and improvements based on their use. Regular updates to training programs, informed by the

latest research and clinical experiences, will ensure that the use of zip ties continues to evolve and improve.

Advancements in Surgical Zip Tie Design: Enhancing Efficacy, Safety, and Sustainability

Surgical Zip Tie Design for Surgical Applications

The optimization of zip tie design for surgical applications represents a significant frontier in enhancing both the efficacy and safety of various medical procedures. As research into zip ties progresses, it is important to consider designs and material properties compatible with all skin types. Human skin varies significantly among individuals in terms of thickness, elasticity, and sensitivity, necessitating the creation of zip ties that acknowledge these differences. One potential innovation is the use of adjustable tension in zip ties with heterogeneous material properties. By incorporating zip ties with reliable yet variable tensile strength, the force applied to the skin can be tailored to the individual, enhancing safety. Additionally, the use of materials that minimize the risk of skin reactions, including contact and allergic dermatitis, is essential. A notable study assessed bacterial penetration and subsequent infection symptoms in traditional sutures versus a new tape-based, zip-type wound closure technology under conditions mimicking real-life stress [18]. This device consists of two polyurethane strips attached to either side of the wound with a hydrocolloid pressure-sensitive skin adhesive, achieving closure using a series of interconnected nylon zip-tie-type ratcheting straps. In an *in vivo* model designed to replicate these conditions, the zip-type closure performed better than conventional sutures, maintaining wound integrity and reducing bacterial penetration under simulated patient movement [18]. This finding suggests that the zip-type closure can effectively function in the challenging and dynamic environment of a healing wound exposed to patient movement. The superior performance demonstrates the strength of the materials combined with their precise placement. Furthermore, materials may be developed to reduce inflammatory responses, such as novel biocompatible polymers or innovative coatings, to further mitigate the risk of discomfort and excessive scar tissue formation. The combination of mechanical integrity, precise application, and biocompatible materials enhances the overall efficacy and outcomes in wound management.

Given the anatomical variability of surgical sites, design flexibility is essential to adapt to these various features. Zip ties intended for use in human anatomy must be particularly ergonomic, allowing for easy application and adjustment of tension in otherwise difficult-to-access and anatomically challenging regions, including both open and minimally invasive procedures. Zip ties require a design that provides a secure grip and can remain in place for the duration of the surgical procedure. Manufacturing should incorporate specific surface textures or locking mechanisms tailored for use within surgical settings. Future customizable designs are anticipated to leverage the true advantages of zip ties in medicine. As versatility in application is key, a design that can be used across various surgical sites, from delicate procedures involving facial structures to applications in abdominal or orthopedic surgeries, will broaden its utility. Current evaluations have mainly focused on comparing zip tie sutures to various other suture techniques within specific anatomical regions, without further comparing them across different sites [27,35]. For example, Tian et al.'s meta-analysis investigated the efficacy and safety of zip-type skin closure devices compared to surgical staples for wound closure in patients undergoing total knee arthroplasty in a total of 3,550 knees [27]. The study concluded that zip-type skin closure devices perform better than staples in this anatomical region, with

lower wound pain and scar scores, as well as lower readmission rates. This implies that future investigations should broaden the scope of anatomical regions studied to fully understand the versatility and effectiveness of zip-type closures. Versatility and specialized adaptations will enable the development of designs that address specific patient needs, such as skin type, surgical site, and procedure details, leading to enhanced patient safety. Comparative studies across various surgical sites will be necessary to validate their universal applicability and identify any region-specific advantages or limitations.

Sustainability and Material Considerations

Biodegradable polymers that degrade naturally without the need for removal could broaden the application of zip ties and eliminate long-term complications from non-removal. These materials would need to be strong and stable to retain the zip tie's strength and position, supporting tissue healing and recovery in the weeks following surgery. One recent study assessed the performance of biodegradable albumin-based sutures in various clinical settings [36]. The researchers focused on key parameters such as biodegradability, biocompatibility, tissue regeneration, and customization potential. The results indicated that these sutures degraded at a predictable rate, matching the tissue healing timeline, thus eliminating the need for suture removal. Additionally, the high biocompatibility of albumin-based sutures minimized adverse reactions and significantly reduced the incidence of inflammation and infection. Furthermore, the study demonstrated that albumin-based sutures enhanced tissue regeneration by promoting cell adhesion and proliferation, leading to improved wound healing. The ability to customize the composition and structure of these sutures allowed for tailored mechanical properties and degradation rates, making them suitable for a wide range of tissue engineering applications, especially zip tie sutures. Future explorations of this combination would yield valuable results.

Developing new hypoallergenic materials would additionally make a meaningful contribution, especially for patients with a predisposition for skin sensitivities. Materials that reduce inflammatory responses, such as novel biocompatible polymers or innovative coatings, can mitigate the risk of discomfort and excessive scar tissue, while facilitating successful closure of surgical sites. Shao et al. demonstrated the importance of considering the biological environment when designing materials through a study on chitosan-based nanofiber membranes with silver nanoparticles revealing proteins in fetal bovine serum can alter silver release kinetics and reduce long-term antibacterial efficacy compared to inorganic ions in phosphate-buffered saline [37]. Despite this, membranes with higher silver nanoparticle loading maintained antibacterial effects in vivo without negatively impacting wound healing. These findings highlight the potential for using silver-containing biomaterials in developing advanced surgical tools, such as antimicrobial-coated zip ties, to enhance infection control while promoting effective wound healing. This could offer the dual benefits of reducing surgical site infections while also decreasing healthcare spending associated with the use of increasingly expensive antimicrobial medications. Optimizing material design and ensuring flexibility in design significantly enhances the utility of this tool in surgical settings.

The sustainability of the production, use, and disposal of zip ties are additional key components to consider. James et al.'s investigation into biodegradable polymer sutures coated with nanosilver pertains to this context, as materials used ensured biodegradability and enhanced antibacterial properties by combining polycaprolactone,

which degrades naturally in the body, and polyethylene glycol, which serves as a biocompatible solvent to disperse nanosilver particles [37]. This study confirmed the mechanical integrity, biodegradability, and antibacterial efficacy of these sutures as a more sustainable surgical practice. This emphasizes the importance of continuing research into biodegradable and environmentally conscious medical materials. If biodegradable materials can effectively reduce medical waste and minimize the ecological footprint of surgical practices, they add significant value to these innovations. Additional future research should also address how biodegradable materials can be produced sustainably. Focusing on product sustainability will improve the understanding of biodegradable materials' effects and lead to the development of medical zip ties that are safer for patients while simultaneously contributing to a more sustainable healthcare system. Developing a high-quality, biodegradable yet sustainable material for future zip ties could set new industry standards for sutural and surgical devices.

Conclusion

The usage of surgical zip tie skin closures in surgical procedures represents a significant advancement in wound management with the potential to significantly improve patient care. Current research and clinical evidence highlight the efficacy of zip tie closures in promoting wound healing, minimizing dehiscence, and achieving optimal cosmetic results compared to traditional suturing methods. These devices offer secure wound approximation, reduced tension on wound edges, and increased recovery times with lower incidences of infection and scarring. Future investigations should aim to optimize zip tie designs and material properties to ensure they are compatible with diverse skin types and surgical applications. Innovations in biodegradable and antimicrobial materials could further expand their utility for various types of surgeries, including minimally invasive and robotic-assisted procedures. Multidisciplinary collaboration among surgeons, engineers, and biomaterial scientists is essential for refining zip tie closure systems, conducting rigorous clinical trials, and establishing standardized protocols for their widespread integration into surgical practice. Addressing challenges related to material biocompatibility, mechanical strength, and user ergonomics will be imperative to recognizing the full potential of this technology. Ultimately, surgical zip tie skin closures appear to hold tremendous promise in regard to setting new standards in surgical care while improving patient outcomes through innovation and evidence-based practice.

References

1. Carli AV, Spiro S, Barlow BT, Haas SB (2017) Using a non-invasive secure skin closure following total knee arthroplasty leads to fewer wound complications and no patient home care visits compared to surgical staples. *The Knee* 24: 1221-1226.
2. Menkowitz B, Olivieri G, Belson O (2020) Patient Satisfaction and Cosmetic Outcome in a Randomized, Prospective Study of Total Knee Arthroplasty Skin Closure Comparing Zip Surgical Skin Closure with Staples. *Cureus* <https://www.cureus.com/articles/23595-patient-satisfaction-and-cosmetic-outcome-in-a-randomized-prospective-study-of-total-knee-arthroplasty-skin-closure-comparing-zip-surgical-skin-closure-with-staples#!/>.
3. Shrestha O, Basukala S, Karki S, Thapa N, Bhugai N, et al. (2024) Comparison between novel zipper device and conventional methods for skin closure: a systematic review and meta-analysis. *Ann Med Surg* 86: 1631-1640.
4. Xie C, Yu C, Wang W, Wang C, Yin D (2020) A novel zipper device versus sutures for wound closure after surgery: a systematic review and meta-analysis. *Int Wound J* 17: 1725-

- 1737.
5. Ovington GL (2023) Surgical Wound Closure and Healing. In: Colette Maurício A, Alvites R, Gönül M, editors. *Wound Healing - Recent Advances and Future Opportunities*. Intech Open <https://www.intechopen.com/chapters/82674>.
 6. Harn HI, Ogawa R, Hsu C, Hughes MW, Tang M, et al. (2019) The tension biology of wound healing. *Exp Dermatol* 28: 464-471.
 7. Tulloh B, Lee D (2007) Approximating tissues in: *Foundations of Operative Surgery an Introduction to Surgical Techniques*. Oxford University Press Oxford 3–110 <https://academic.oup.com/book/52668/chapter/421835868>.
 8. Li Y, Pan M (2016) Medical zip fastener of surgery wound <https://patents.google.com/patent/CN112190394A/en>.
 9. Francisco Sergio Pinheiro Regadas Method for anastomosis surgery using zip-ties (2008) <https://patents.google.com/patent/US8211129B2/en>.
 10. Cuddy LC (2017) Wound Closure Tension-Relieving Techniques, and Local Flaps. *Vet Clin North Am Small Anim Pract* 47: 1221-1235.
 11. Fu D, Huang J, Wu X, Li Y, Zhang Y, et al. (2024) Shape-fixing hydrogel promotes scarless healing of wounds under tension. *Acta Biomater* 183: 173-190.
 12. Zhang S, Nabi O, Jiang X (2021) New strategy of modulating incision tension: A wound tension offloading device applied before surgery. *Dermatol Ther* 34. <https://onlinelibrary.wiley.com/doi/10.1111/dth.14797>.
 13. Devick IF, Hendrickson DA (2021) Complications Associated with Sutures. In: Rubio-Martinez LM, Hendrickson DA, editors. *Complications in Equine Surgery 1st ed* Wiley <https://onlinelibrary.wiley.com/doi/10.1002/9781119190332.ch9>.
 14. Bartlett LC (1985) Pressure necrosis is the primary cause of wound dehiscence. *Can J Surg J Can Chir* 28: 27-30.
 15. Feather CB, Rehrig S, Allen R, Barth N, Kugler EM, et al. (2024) To close or not to close? Wound management in emergent colorectal surgery, an EAST multicenter prospective cohort study. *J Trauma Acute Care Surg* 97: 73-81.
 16. Tran Q, Richter U, Bair J, Richter S, Albert A, et al. (2024) Primary vs. secondary wound closure following transvenous system explantation in CIED infection. *Europace* 26: euae 102.512.
 17. Mun J, Hyun SJ, Lee JK, An S, Kim KJ (2023) Surgical and Clinical Outcomes Associated with the Use of Barbed Sutures and Self-Adhering Mesh System and Polymeric Glue for Wound Closure in Multilevel or Revision Spinal Surgery: A Matched Cohort Comparative Study with Conventional Wound Closure Procedure. *Neuro spine* 20: 981-988.
 18. Safa B, Belson A, Meschter C, Kelley M, Stewart D, et al. (2018) In Vivo Efficacy Study Showing Comparative Advantage of Bacterial Infection Prevention with Zip-type Skin Closure Device vs Subcuticular Sutures. *Cureus* <https://www.cureus.com/articles/12205-in-vivo-efficacy-study-showing-comparative-advantage-of-bacterial-infection-prevention-with-zip-type-skin-closure-device-vs-subcuticular-sutures>.
 19. Greenbaum S, Zak S, Tesoriero PJ, Rudy H, Vigdorichik J, et al. (2021) A Single-Center Randomized Prospective Study Investigating the Efficacy of Various Wound Closure Devices in Reducing Postoperative Wound Complications. *Arthroplasty Today* 9: 83-88.
 20. Germano N, Gonçalves I, Moya B, Ribeiro R (2010) Vacuum-assisted closure of laparostomy, an efficient strategy for complicated intra-abdominal infection. *Crit Care* 14: P389.
 21. Roolker W, Kraaneveld E, Been H, Marti R (2002) Results of a prospective randomised study comparing a non-invasive surgical zipper versus intracutaneous sutures for wound closure. *Arch Orthop Trauma Surg* 122: 2-4.
 22. Hasse FM, Rademacher C, Bokel G (1999) Prospective study of the MEDIZIP surgical zipper in relation to efficacy of skin closure, course of wound healing, and results of the healing process in surgical wounds. *Zentralbl Chir* 124: 210-213.
 23. Melly L, Gahl B, Meinke R, Rueter F, Matt P, et al. (2013) A new cable-tie-based sternal closure device: infectious considerations†. *Interact Cardiovasc Thorac Surg* 17: 219-224.
 24. Moy RL, Waldman B, Hein DW (1992) A Review of Sutures and Suturing Techniques. *J Dermatol Surg Oncol* 18: 785-795.
 25. Berman B, Maderal A, Raphael B (2017) Keloids and Hypertrophic Scars: Pathophysiology, Classification, and Treatment. *Dermatol Surg* 43: S3-S18.
 26. Chen D, Song J, Zhao Y, Zheng X, Yu A (2016) Systematic Review and Meta-Analysis of Surgical Zipper Technique versus Intracutaneous Sutures for the Closing of Surgical Incision. *Zhang L, editor. PLOS ONE* 11: e0162471.
 27. Tian P, Li Y min, Li Z jun, Xu G jun, Ma X long (2021) Comparison between Zip-Type Skin Closure Device and Staple for Total Knee Arthroplasty: A Meta-Analysis Kim SH editor. *BioMed Res Int* 13: 1-5.
 28. Ko JH, Yang IH, Ko MS, Kamolhuja E, Park KK (2017) Do zip-type skin-closing devices show better wound status compared to conventional staple devices in total knee arthroplasty? *Int Wound J* 14: 250-254.
 29. Onuminya JE, Onabowale BO (2002) A prospective evaluation of Medizip in Nigeria. *West Afr J Med* 21: 15-18.
 30. Onuminya JE, Alufohai E, Onuminya DS (2006) Outcome of surgical zipper technique. *J Natl Med Assoc* 98: 83-85.
 31. Tanaka Y, Miyamoto T, Naito Y, Yoshitake S, Sasahara A, et al. (2016) Randomized Study of a New Noninvasive Skin Closure Device for Use After Congenital Heart Operations. *Ann Thorac Surg* 102: 1368-1374.
 32. Koninckx PR, Ussia A, Wattiez A, Kondo W, Romeo A (2023) Laparoscopic Surgery: A Systematic Review of Loop and Knot Security, Varying with the Suture and Sequences, Throws, Rotation and Destabilization of Half-Knots or Half-Hitches. *J Clin Med* 12: 6166.
 33. Nogueira LR, Lustosa KA, Galindo LAO, Castro SED, Picanço LR, et al. (2023) Assessing Endoscopic Suture Performance of Gynecology and Obstetrics Residents Following Methodic Training. *Rev Bras Ginecol E Obstetricia RBGO Gynecol Obstet* 45: e603-e608.
 34. Wessel KJ, Wendenburg I, Varnava C, Wellenbrock S, Dermietzel A, et al. (2024) Ideal suturing technique for robot-assisted microsurgical anastomoses. *J Robot Surg* 18: 272.
 35. Teixeira BG, Faustino EG, Zangrando D, Horikawa FK, Shinohara EH, et al. (2023) Self-locking zip ties temporary displaced mandibular fracture reduction. *Braz J Implantol Health Sci* 5: 5054-5063.
 36. Naser MA, Sayed AM, Abdelmoez W, El-Wakad MT, Abdo MS (2024) Biodegradable suture development-based albumin composites for tissue engineering applications. *Sci Rep* 14: 7912.
 37. James B, Ramakrishnan R, Aprem AS (2021) Development of Environmentally Safe Biodegradable, Antibacterial Surgical Sutures Using Nanosilver Particles. *J Polym Environ* 29: 2282-2288.

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