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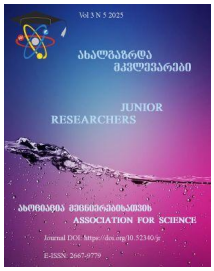

Advances in Wound Closure Techniques: Integrating Functional Preservation and Aesthetic Outcomes

Arjun Jay Prakash[1], Vasanthapriya Jeevanandam[2], Mohammed Murtada[3], Muzna Amir Ali[4], Hinaz Jameela[5].

[1]Ivane Javakishvili Tbilisi State University, Tbilisi, Georgia
[2]Tbilisi State Medical University, Tbilisi, Georgia
[3]Tbilisi State Medical University, Tbilisi, Georgia
[4]Jinnah Medical and Dental College, Karachi, Pakistan
[5]Tbilisi State Medical University, Tbilisi, Georgia
Corresponding author: Arjun Jay Prakash, Ivane Javakishvili Tbilisi State University, Tbilisi, Georgia; Tel: +974-66191967; Email: arjunatschool@gmail.com
Orcid:
Arjun Jay Prakash: 0009-0002-2063-0192
Vasanthapriya Jeevanandam: 0000-0002-7715-9787
Mohammed Murtada: 0009-0000-4505-4262
Muzna Amir Ali: 0009-0004-5678-5764
Hinaz Jameela: 0009-0008-9917-0013

Abstract:

Wound closure is a cornerstone of surgical practice, extending from acute management to complex reconstructive procedures, with implications for tissue healing, infection prevention, and long-term patient satisfaction. Traditional suturing techniques, including interrupted and continuous methods, remain foundational, offering flexibility in tension management and cosmesis. Recent innovations such as subcuticular suturing with absorbable monofilaments, barbed sutures, and cyanoacrylate tissue adhesives have demonstrated improved operative efficiency, reduced complication rates, and superior short-term aesthetic outcomes. Negative pressure wound therapy and closed incision negative pressure therapy further enhance healing in high-risk patients, minimizing surgical site complications and optimizing scar quality. Scar management strategies, particularly for hypertrophic scars and keloids, increasingly employ multimodal approaches combining conservative measures, intralesional corticosteroids, 5-fluorouracil, and emerging agents like botulinum toxin A to achieve functional and cosmetic restoration. At the reconstructive level, advancements in microvascular anastomosis, including coupling devices, have improved efficiency and reliability in free tissue transfer, although patient- and procedure-specific considerations remain critical. Collectively, these developments reflect a paradigm shift: wound closure is no longer solely a mechanical task, but a

deliberate process aimed at preserving tissue function, optimizing aesthetic outcomes, and enhancing overall patient-centered care. Future practice will likely focus on personalized approaches that integrate novel suture technologies, advanced wound therapies, and targeted scar modulation to achieve optimal surgical outcomes.

Keywords: wound closure, tissue healing, negative pressure wound therapy, scar management, microvascular reconstruction.

Introduction:

Wound closure is an integral part of all aspects of healthcare, from acute response, to elective reconstructive procedures playing a central role in restoring tissue continuity, promoting wound healing and also in preserving the functional and aesthetic outcomes affecting long-term patient satisfaction and welfare. It also is directly responsible for preventing infection, scarring, and is integral for the overall success of any surgical procedure, especially the high cosmetic detail in reconstructive techniques [17].

The foundation of surgical practice for closing skin and fascia has been traditional suturing techniques, which are mainly divided into continuous and interrupted sutures, and can be laborious with increased possibility of scarring or tissue damage. Interrupted suturing utilizes separate stitches, each individually tied, allowing for accurate variation of tension and the accommodation of localized complications such as wound dehiscence, without compromising the integrity of the closure. The continuous suturing technique, in contrast, uses a single thread to make a series of stitches along the wound, with both ends tied in knots. It is known to distribute tension evenly across the wound, be expedient, and decrease operative time [1].

Innovations in suture technology:

Advancements have been made on all aspects of wound care, with novel suturing techniques and materials and wound management, with increasing focus on cosmetic results, scar and Surgical Site Infections (SSIs) prevention and management. New techniques such as the transdermal and subcutaneous continuous sutures were compared by a meta analysis to demonstrate improved wound management and cosmetic results, compared to interrupted sutures [5]. A meta-analysis [1], contrasted between continuous and interrupted methods to show that continuous sutures, both transdermal and subcuticular, had significantly higher patient and observer Visual Analogue Scale (VAS) scores for cosmetic appearance compared to interrupted sutures. Additionally, reduced incidence of wound dehiscence was also observed with continuous sutures, making it the better choice [1].

Another common choice is between absorbable and non-absorbable sutures, since it significantly impacts outcomes, especially in cosmetically sensitive areas such as the face. A meta-analysis comparing

closure of facial skin revealed no statistically significant difference between them indicating that the suturing technique plays a major role in the results, perhaps even more than the material [2]. However, absorbable sutures eliminate the suture removal process, minimizing patient anxiety and resource use [2].

Among traditional methods, subcuticular suturing is highly valued for its aesthetic qualities. It is a continuous technique that involves placing stitches beneath the epidermal layer avoiding suture track scarring and limiting external suture marking. When these techniques are critically examined, context-dependent advantages become apparent. It has been demonstrated that interrupted sutures are more secure in high-tension areas or contaminated wounds, and continuous sutures, particularly subcuticular ones, work incredibly well in elective settings where cosmesis and efficiency are paramount concerns [3]. Additionally, combining the best techniques, such as Subcuticular suturing with slowly absorbing monofilament sutures, with an optimal suture length-to-wound ratio of at least 4:1, produces the best results [3]. Overall, each of these techniques offer unique advantages and instead of a one-size-fits-all strategy, the evidence emphasizes that the best technique depends on the surgical context, patient characteristics, and surgeon expertise.

Structural innovation in suture technology has led to the development of barbed sutures which self-anchors into the tissue, eliminating the need for knots. These sutures have unidirectional or bidirectional barbs that latch into the tissue and secure it without the need for manual tying, reducing operative and wound closure times. A recent meta analysis [4] in spinal surgery shows considerably reduced operative time and wound closure duration compared to conventional sutures, while maintaining similar rates of postoperative wound complications, infection, hematoma, and seroma formation. They also allow decreased dead space as they are knotless, decreasing fluid accumulation and reducing the risk of hematoma and infection. They have been shown to maintain high tensile strength and better resist dehiscence under cyclical loading compared to traditional braided sutures. Some barbed sutures are often coated with antimicrobial agents such as STRATAFIX™, combining two separate innovations to improve suture design [4]. Economical analysis of barbed sutures show a high upfront cost, though there is significant long-term cost saving per patient due to reduced operating time and prevention of SSIs (one of the most expensive surgical complications) .

However, multiple practical challenges such as a higher upfront cost, lack of randomized controlled trials (RCTs) and high heterogeneity in patient populations, surgical techniques, and follow-up durations. These developments indicate that sutures have massive potential to improve all aspects of wound care, and long-term research should be promoted to provide evidence, driving adoption into surgical and clinical practice [4,5].

Alternative materials in wound care:

A modern alternative to traditional sutures are Cyanoacrylate tissue adhesives (CTAs), which are particularly beneficial for skin closure in delicate areas like the face and neck. CTAs work by forming

a durable, plastic film which can effectively approximate the wound edges. The main advantage of CTAs is the rapid and simple process of application eliminating the need for suturing and suture removal. Along with that, benefits such as reduced procedural pain, decreased closure time, and potentially lower costs, can be seen when compared to conventional suture methods [6].

However, it is important to consider functional and aesthetic outcomes when choosing between CTAs and sutures. One meta-analysis of face and neck wounds [6], has observed that even though CTAs provide superior cosmetic results at one month, these gradually drop off over time. While aesthetically superior at month one, they yield results comparable to sutures, at month two; and after three months, sutures produced better cosmetic outcomes. This suggests that the advantages with CTAs are short-lived and hence should be opted for procedures matching those requirements. Furthermore, the type of CTA chosen, between long-chain and short-chain variants, matters, as long-chain variants are preferred due to their longer degradation period and reduced tissue toxicity [6].

Role of Negative Pressure Wound Therapy (NPWT) in Plastic surgery:

NPWT and Closed incision negative pressure therapy (ciiNPT) are novel techniques that utilize vacuums to seal and manage incisions. They are increasingly being used as a prophylactic therapy for high-risk surgical incisions in plastic surgery. Multiple meta-analyses, including a large number of RCTs, have shown that NPWT and ciiNPT, can significantly reduce the incidence of surgical site complications, including wound dehiscence and skin necrosis while also resulting in a shorter hospital stay, improved scar and an overall reduced health cost [8,9,10]. Additionally they have also been proven to be highly effective in the prevention of SSIs as compared to traditional methods [9].

However, choosing the appropriate closure method is often complex and is influenced by factors such as the location of the wound, cosmetic concerns, patient characteristics and cost [6,8,9]. For instance, skin separation is of importance when considering obstetric and gynecologic surgery, and the choice of skin closure material is known to have a direct impact on patient outcomes. A network meta-analysis [7] shows that when compared to staples, absorbable sutures significantly reduce the risk of skin separation, though increasing the operative time, making them the optimal choice. Though a niche usage, it further highlights the importance of patient and procedure matching to find the appropriate materials [7].

Scar prevention and management:

Scars are an unavoidable part of wound healing, but in some cases, especially in hypertrophic scars and keloids, they can cause significant functional, cosmetic, and even psychosocial issues. These arise due to abnormal wound healing where there is excessive collagen deposition, prolonged inflammation, and poor remodeling of the extracellular matrix, leading to thick, raised and often itchy or painful scars that can also restrict movement [12,14].

Several risk factors are now known to play a role in scar formation, local ones like wound tension, systemic conditions such as hypertension, and even genetic predisposition. This makes treatment highly individualized. For hypertrophic scars, mild cases are usually managed conservatively while severe contractures may need surgical release. In keloids, management depends on their size and number: small single lesions may be excised and followed by adjuvant therapy, while larger or multiple lesions often require staged or combination approaches [12].

Conservative management remains the starting point. Silicone gel sheeting is one of the most widely used non-invasive options. It works by creating a hydrated environment over the scar, which helps reduce pigmentation, height and discomfort. Multiple studies have shown it to be effective and it continues to be considered the first-line tool for hypertrophic scars [11]. Other commonly used measures include taping, compression therapy, corticosteroid injections, and laser treatments.

Among active interventions, intralesional corticosteroids such as Triamcinolone Acetonide (TAC) are still considered the gold standard. However, more recent evidence shows that combining TAC with 5-fluorouracil (5-FU) gives better results, particularly in reducing scar thickness, redness and stiffness, as well as relieving pruritus [13,15]. Despite this, TAC carries risks like skin atrophy and both agents can be associated with recurrence. Newer options like verapamil and botulinum toxin A (BTA) have also been studied for their effect on collagen modulation, and network analyses suggest that combining them with TAC may further improve outcomes, especially in patients with severe or multiple keloids [13,15].

Overall, current practice favors a multimodal approach, tailoring treatment to the patient and the scar type, often combining surgery with pharmacological and conservative methods to achieve the best possible functional and cosmetic results.

Advances in microvascular anastomosis and infection control:

Advanced microvascular free tissue transfer is now one of the most important techniques in reconstructive surgery. The success of these procedures depend on effective microvascular anastomosis, as venous complications remain the leading cause of free flap failure. Traditionally, anastomoses are hand-sewn, but this is time-consuming and carries risks such as thrombosis and vessel kinking. To overcome these issues, mechanical anastomotic coupling devices have been developed. These devices approximate vessel ends mechanically, simplifying the process and reducing operative time [16,17,18].

Evidence regarding their effectiveness has been mixed. A systematic review of 11 retrospective case series examining venous thrombosis in free flap anastomosis found no difference in thrombosis rates between coupling devices and traditional sutures. This suggests that while coupling devices may simplify the procedure, they do not specifically reduce the risk of thrombosis [16]. For this reason, arterial anastomoses are still usually performed with sutures, while venous anastomoses are the preferred indication for coupling devices. A separate systematic review of 15 retrospective case series

investigating arterial use, also showed negligible differences in thrombosis rates compared to hand-sewn techniques, supporting their safety but not showing clear superiority [17].

Despite their advantages, coupling devices are not without limitations. They require vessels of suitable size and quality, and are not effective in very small or calcified vessels. Their high cost and need for multiple device sizes also make them impractical in resource-limited settings [16,17,18].

Conclusion:

Wound closure has evolved from a basic surgical necessity into a field that balances healing, infection control, and aesthetic outcomes, which are particularly relevant in reconstructive and plastic surgery. No single method is universally superior; instead, the best choice depends on wound characteristics, anatomical location, and patient factors. Traditional suturing techniques remain the foundation, but refinements such as subcuticular suturing with absorbable monofilaments, barbed sutures, and cyanoacrylate adhesives highlight the ongoing shift towards efficiency and improved cosmetic results. Similarly, negative pressure wound therapy has proven highly effective in reducing complications in high-risk patients, further emphasizing the importance of tailoring closure strategies to both risk and context.

Scar management remains a central challenge, with hypertrophic scars and keloids requiring individualized multimodal strategies that combine surgery with pharmacological interventions such as corticosteroids, 5-FU, or emerging agents like botulinum toxin A. Understanding the influence of mechanical tension and systemic risk factors is equally important to guide prevention and long-term outcomes.

At the reconstructive level, innovations in microvascular anastomosis, including coupling devices, represent another step toward efficiency and reliability, although their benefits remain procedure- and patient-dependent. Together, these developments reflect a broader paradigm shift: closure is no longer just about sealing a wound, but about restoring tissue continuity while preserving form, function, and patient satisfaction. The future of wound closure will likely lie in a personalized approach that integrates novel suture technologies, advanced wound therapies, and targeted scar modulation into reconstructive practice.

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