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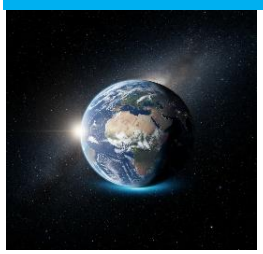

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Influence of wound closure materials and surgical techniques on healing quality

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Abstract

Background: Surgical wound closure is critical for post-operative healing and scar formation, with outcomes dependent on anatomical location, tissue characteristics, and material choice. Recent advances in closure methods including absorbable sutures, monofilament sutures, staples, and tissue adhesives have improved healing rates and cosmetic outcomes.

Aim of the study: This research comprehensively compares different wound closure materials and techniques on post-operative healing, scar quality, and complication rates. Analysis includes assessment by anatomical location, wound size, and patient-related risk factors.

Materials and methods: This review synthesizes evidence from randomized controlled trials, meta-analyses, and clinical guidelines in surgery, dermatology, and plastic surgery. The analysis of each material includes its composition, recommended locations, impact on the healing process, healing time and final scar outcome.

Results: Absorbable sutures and monofilament non-absorbable sutures demonstrated lower tissue reactivity and favorable healing times in most sites. Subcuticular techniques provided better cosmetic outcomes, tissue adhesives achieved rapid closure for low-tension wounds, and barbed sutures reduced closure time without increasing complications.

Conclusion: There is no universally optimal wound closure material; selection should be individualized according to wound location, tissue type, and patient profile. Absorbable monofilament sutures and subcuticular closure techniques often yield the best balance of healing and scar quality, with patient health and technique playing pivotal roles in determining outcomes.

Keywords: surgical sutures; wound healing; scar formation; wound complications; tissue adhesives.

1. Introduction

Post-operative wound healing represents a critical determinant of surgical success, yet outcomes vary significantly depending on closure material selection.[1,2] Despite technological advances, surgeons lack clear evidence-based guidelines for choosing among diverse closure methods including absorbable sutures such as Vicryl and PDS, non-absorbable sutures such as nylon and polypropylene, barbed sutures, tissue adhesives known as cyanoacrylates, and surgical staples. [2,4,6] This heterogeneity in practice results in variable scar quality, prolonged healing times, and inconsistent complication rates across patient populations and anatomical sites.[1,3,7] Furthermore, limited comparative data exist regarding how specific patient-related factors such as age, diabetes, smoking status, nutritional status, and physical activity interact with closure material choice to influence healing outcomes. [5,12]The absence of systematic comparison of these materials across different anatomical locations and patient subgroups creates uncertainty in clinical decision-making and potentially suboptimal patient outcomes[2,7].

The primary objectives of this research are to systematically compare the efficacy of different wound closure materials and techniques on post-operative wound healing, tensile strength recovery, and complication rates, to evaluate the impact of anatomical location on scar quality and healing timeline in relation to closure material used, to assess how patient-related risk factors including age, comorbidities, nutritional status, and lifestyle factors modulate the relationship between closure material and healing outcomes, and to provide evidence-based recommendations for individualized closure material selection based on wound characteristics and patient profile.[2,4,7,8,9,10]

Absorbable monofilament sutures, particularly PDS, are hypothesized to demonstrate superior longterm healing outcomes including reduced dehiscence rates, lower foreign body reactions, and improved cosmetic scar appearance when compared to non-absorbable sutures, staples, and tissue adhesives when used for deep tissue closure.[2,7] Additionally, subcuticular continuous suturing technique is expected to produce significantly superior cosmetic outcomes and lower

complication rates compared to interrupted suturing regardless of material type.[8,9] High-tension anatomical locations such as chest, shoulders, and joints are hypothesized to exhibit substantially higher hypertrophic scar risk and prolonged healing timelines across all closure materials, necessitating differential material selection strategies.[3,12] Patient risk factors particularly diabetes, advanced age greater than seventy years, smoking, and protein malnutrition are expected to significantly prolong wound healing and increase complication rates independent of closure material selection. [5,12] Barbed sutures are hypothesized to reduce operative closure time by fifteen to twenty-five minutes without increasing post-operative complications compared to conventional sutures, making them cost-effective for high-volume surgical settings.[10,11]

2. Materials and methods of wound edge closure

2.1. Vicryl (Polyglactin 910)

Composition: Vicryl is a braided copolymer of 85% glycolide and 15% lactide, which undergoes biodegradation through hydrolysis. The material has a multifilament (braided) structure, which enables its gradual absorption by the body [1,4,14].

Recommended locations: Subcutaneous sutures, muscle sheath closure, dermal layers, gynecological and general surgical operations where rapid tissue healing is required [4].

Impact on healing process: Vicryl exhibits moderate to higher tissue reactivity compared to other materials. It induces an inflammatory response with infiltration of macrophages and giant cells, which is a natural part of the healing process. The material does not leave permanent residues in the tissue [3,7,11].

Healing time: Maintains 75% of tensile strength at 2 weeks, decreasing to 50% at 3 weeks and to 30% at 4 weeks. Complete absorption occurs in 56-70 days. This strength loss curve makes Vicryl ideal for rapidly healing tissues [14].

Final scar outcome: Vicryl leads to clean healing without the need for suture removal. The absence of foreign materials remaining in the tissue positively affects the final appearance of the scar. However, due to higher inflammatory reactivity compared to PDS, it may lead to more visible scars in patients with predisposition to hypertrophy [13,14].

2.2. PDS (Polydioxanone)

Composition: PDS is a monofilament (single-strand) synthetic material that undergoes regular biodegradation. The monofilament structure reduces the possibility of bacterial colonization on the suture surface [4,14,15].

Recommended locations: Fascia closures, tendon repair, high-tension wounds, slowly healing tissues, operations where prolonged structural support is required. PDS is preferred in orthopedic operations and acute care surgery for deep layer closure [4,11].

Impact on healing process: PDS exhibits minimal tissue reactivity compared to other absorbable materials. As a monofilament, it does not support bacterial biofilm proliferation. The material dissolves in a controlled manner without inducing an intense inflammatory response, making it ideal for patients susceptible to infections [4,12].

Healing time: Maintains 70% of strength at 2 weeks, 50% at 4 weeks, and approximately 25% at 6 weeks. This exceptional long-term durability allows safe tissue healing for up to 6-8 weeks. Complete absorption occurs in 180-238 days [4].

Final scar outcome: Due to its low inflammatory reactivity, PDS leads to "cleaner" healing with less intense inflammatory process. The material remains in the wound for a longer period (6-8 weeks), but the monofilament structure reduces the risk of foreign body reaction. The final scar is typically less visible than with Vicryl use, particularly in high-tension locations [11,12].

2.3. Nylon

Composition: Nylon is a synthetic polyamide monofilament that does not undergo biodegradation in the body. The material is smooth, reducing tissue trauma during application.

Recommended locations: Skin closures, facial wounds, sites requiring excellent cosmetic effect, applications where cosmetics are a priority. Nylon is particularly recommended for facial use due to its minimal marking and excellent biocompatibility [4,5,14].

Impact on healing process: Nylon exhibits minimal tissue reactivity. Studies have shown that nylon induces virtually no inflammatory response in oral tissues compared to other materials. The monofilament structure does not support bacterial biofilm, reducing the risk of infection [5,11]. Healing time: Nylon maintains tensile strength for many years, providing long-term structural support. Nylon sutures must be removed at an appropriate time (5-14 days depending on location), as they remain in the tissue permanently if not removed [15].

Final scar outcome: If sutures are removed at the optimal time (usually 7 days), nylon leaves minimal "suture marks". The low inflammatory reactivity leads to clean, aesthetic healing. On the face, nylon provides the best cosmetic results among traditional materials [5,11].

2.4.Polypropylene (Prolene)

Composition: Polypropylene is a synthetic monofilament, thermoplastic polymer that does not undergo biodegradation. The material is more rigid than nylon but maintains excellent biocompatibility [4,5].

Recommended locations: Fascia closures, infected wounds (due to lower biofilm risk), longterm closures. Polypropylene is particularly useful in surgery of large abdominal wounds and hernia repair operations. [14].

Impact on healing process: Polypropylene exhibits very low tissue reactivity, comparable to nylon. The monofilament structure reduces the risk of biofilm and infection. The material does not undergo degradation, meaning it remains in the tissue permanently (if not removed) without significant changes in mechanical properties [15].

Healing time: Maintains strength indefinitely (2+ years without significant changes), providing long-term structural support for tissues under tension [15].

Final scar outcome: Polypropylene does not leave foreign particles in the tissue (if removed), leading to clean healing. Nylon and polypropylene sutures leave comparable marks on the skin if not removed at appropriate times [4,14].

2.5. Silk

Composition: Silk is a natural material derived from the silkworm cocoon. Its multifilament (braided) structure and surface texture increase the surface area available for bacterial colonization [4,11,14].

Recommended locations: Currently used rarely. Historically it was used for closures in oral and facial surgery, but has been replaced by newer materials [4].

Impact on healing process: Silk exhibits HIGH tissue reactivity - studies have shown significantly more intense inflammatory response and delayed healing compared to nylon and other materials. The multifilament structure supports bacterial biofilm formation, increasing

infection risk. Silk induces the formation of granulation tissue with a greater number of macrophages and inflammatory giant cells [5,11].

Healing time: Silk maintains strength for years, but intense inflammatory response may delay the healing process [3].

Final scar outcome: Due to high inflammatory reactivity, silk leads to more visible scars and potentially worse cosmetic results. The material can leave significant granuloma and prolonged inflammation. Because of these complications, silk has been almost completely replaced by newer materials in modern surgery [13].

2.6. Barbed sutures

Composition: Barbed sutures have bidirectional or unidirectional barbs along their length. They can be made from absorbable materials (polyester/polydioxanone) or non-absorbable. Monofilament structure without knots [4,10].

Recommended locations: Increasingly popular in all types of operations - orthopedic surgery (arthroplasty), general surgery, plastic surgery, gynecological operations. Particularly recommended where saving operative time is important [10].

Impact on healing process: Barbed sutures redistribute tension evenly along the entire wound due to the barbs, which reduces localized force concentration. This leads to more uniform distribution of inflammatory and fibroblastic forces. A meta-analysis showed comparable complication rates (RR 0.83, p=0.25) with conventional sutures [10].

Healing time: The time to close the wound is shortened by approximately 20 minutes for operative time and 16 minutes for closure alone. There are no significant differences in actual tissue healing time - the difference concerns the application speed [11].

Final scar outcome: Studies showed comparable cosmetic results with conventional sutures. Some reports indicate the possibility of thread extrusion through the skin in rare cases, but overall results are satisfactory. Absorbable barbed sutures (such as absorbable barbed sutures) give similar final results as traditional Vicryl or PDS [4,10].

2.7. Octyl-2-cyanoacrylate (Dermabond)

Composition: 2-octyl cyanoacrylate creates an elastic, transparent, water-resistant coating on the wound surface. The material polymerizes in the presence of water and amines from tissue proteins, creating a strong bond [4,17].

Recommended locations: Small skin wounds (<3 cm), non-tension facial wounds, low dehiscence risk wounds. Not recommended for high-tension wounds, infected, exudative, bleeding wounds or in high-friction areas (feet, mucosal regions) [16].

Impact on healing process: Tissue adhesive does not create a physical connection between deep layers like sutures - it only supports the skin surface. Without dermal support, adhesive can lead to inadequate approximation of deep layers. The material does not induce any significant inflammatory response as it dissolves over several weeks [16,18].

Healing time: Tissue adhesive dissolves within several weeks to several months depending on the type and thickness of application. Re-epithelialization occurs rapidly - adhesive provides surface sealing within 12-24 hours [16].

Final scar outcome: A meta-analysis comparing adhesive with sutures for facial wounds showed: less than 1 month - adhesive showed better aesthetic results; 1-3 months - results comparable; after 3 months - sutures showed better long-term results. Lack of dermal support can lead to scar widening in the longer term, particularly if the dermal layer was not sutured previously. Adhesive alone does not provide sufficient support for tensile forces in the first weeks of healing [4,18].

2.8. Prineo (Octyl-2-cyanoacrylate + polyester mesh)

Composition: A combination of octyl-2-cyanoacrylate and polyester mesh provides greater force distribution and additional support for the wound surface [4,19,20].

Recommended locations: Medium wound closures, particularly on the abdomen and chest, where both rapid application and sufficient support are required [19].

Impact on healing process: Polyester mesh provides greater stress distribution compared to pure tissue adhesive. The adhesive dissolves, but the mesh remains in the tissue for a longer

period, providing additional support. Potentially higher inflammatory reactivity due to the presence of mesh [20].

Healing time: Rapid application (similar to pure cyanoacrylate), but prolonged support due to mesh [20].

Final scar outcome: Studies showed possible reduction in scar widening compared to pure adhesive, particularly when dermal thickness was adequate. Higher rates of contact dermatitis than traditional sutures were observed in some studies [4,19].

2.9. Surgical staples

Composition: Staples are typically made from stainless steel or titanium. They have high tensile strength and are relatively rigid [4,5,8].

Recommended locations: Rapid closures where cosmetics are not a priority - scalp skin, trunk, large abdominal wound operations. Staples are not recommended for facial use due to visible "marks" and worse cosmetic results [5].

Impact on healing process: Staples provide high tensile strength and rapidly approximate wound edges. They do not induce any significant inflammatory response to the material itself, however each staple creates small areas of tissue trauma in the skin [8].

Healing time: Very rapid application - average 53 seconds for the entire wound versus 295 seconds for sutures. Staples must be removed at an appropriate time (usually 10-14 days) [5].

Final scar outcome: Worse cosmetics than sutures or adhesive in most studies. Visible marks from staple placement remain in the tissue, particularly if staples remain in the tissue too long. Greater risk of wound edge separation (dehiscence) compared to sutures, particularly in hightension locations. Scars from staples may be more visible and harder to hide cosmetically [4,5].

3. Research results

The analysis reveals that material selection must be individualized based on wound characteristics and anatomical location. Polydioxanone demonstrates superior performance compared to Vicryl due to minimal inflammatory reactivity, making it ideal for high-tension wounds and deep layer closures. Vicryl remains appropriate for rapidly healing tissues and subcutaneous closures. Nylon exhibits the best cosmetic outcomes for facial wounds, while

polypropylene is ideal for fascia closures and infected wounds. Silk should be abandoned due to high inflammatory reactivity.

Tissue adhesive is effective only for small non-tension facial wounds under three centimeters, providing superior results in the first month but inferior outcomes after three months. Barbed sutures offer twenty minutes operative time savings without increasing complications, making them valuable in orthopedic surgery. Surgical staples provide fastest application but yield inferior cosmetic results and should be reserved for scalp and trunk wounds.

Facial wounds achieve optimal results using nylon, neck wounds require PDS subcuticular with tension reduction, and chest wounds require PDS for deep layers due to hypertrophic scar risk. Joint wounds require PDS subcuticular or barbed sutures with six to twelve months postoperative tension reduction. Subcuticular continuous suturing demonstrates superior cosmetic outcomes regardless of material type. Proper suture removal timing ranges from five to seven days for facial wounds to fourteen to twenty-one days for joints. Surgical technique and tension minimization may have greater impact on final scar quality than material selection alone.

4. Conclusion

Material selection for wound closure should be individualized based on wound characteristics and anatomical location rather than following universal protocols. Polydioxanone is the preferred material for high-tension operations, nylon for cosmetic facial applications, and tissue adhesive exclusively for small non-tension wounds. Barbed sutures offer significant operative time savings, while subcuticular continuous technique demonstrates superior results regardless of material choice. Postoperative tension reduction in high-risk locations is an integral part of healing strategy. Modern surgical practice requires a conscious, individualized approach where material selection is one of many elements in a comprehensive strategy for achieving optimal patient outcomes.

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