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Review Article

RELEVANCE OF SUSHRUTA'S BANDAGING PRINCIPLES IN 21ST CENTURY SURGICAL CARE

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ABSTRACT

Sushruta described 14 types of bandaging methods (*Bandhana Karma*), each specifically designed according to the anatomical location and nature of the wound, with emphasis on infection prevention, pressure regulation, and patient comfort. His use of natural materials such as cotton, silk, and herbal preparations reflects a sophisticated understanding of wound healing processes and tissue dynamics. **Aim:** This review aims to re-examine Sushruta's bandaging techniques and evaluate their potential integration with contemporary wound care practices, particularly in the management of chronic wounds, antimicrobial resistance, sports injuries and resource-limited healthcare settings. **Methods:** A narrative review approach was adopted to analyse classical descriptions from the *Sushruta Samhita* alongside recent advancements in wound care technologies, including hydrogel-based dressings, antimicrobial nanofibers, and biodegradable polymer systems. **Results:** The findings indicate strong conceptual parallels between ancient and modern practices. For example, *Kosha Bandha* corresponds to contemporary splinting techniques used in fracture care, while *Mandal Bandha* aligns with compression therapy for venous ulcers. Sushruta's emphasis on individualized, region-specific treatment closely mirrors modern personalized wound care approaches. Furthermore, emerging technologies such as drug-eluting dressings and sensor-enabled smart bandages extend his principles toward real-time monitoring and targeted therapeutic delivery. **Conclusion:** The integration of Sushruta's wound care principles with modern biomedical technologies offers a promising framework for developing sustainable, cost-effective, and patient-centered solutions. This interdisciplinary approach has the potential to enhance wound healing outcomes, especially in resource-constrained settings, while preserving and modernizing the foundational knowledge of Ayurvedic medicine.

INTRODUCTION

The *Sushruta Samhita*, recognized as one of the earliest medical compendia, reflects the advanced understanding of surgery and wound care in ancient India. Attributed to Acharya Sushruta (circa 1000 BCE), the text adopts a systematic and holistic approach to healthcare, integrating principles of surgery, anatomy, pathology, and therapeutics. It provides detailed accounts of surgical instruments and operative techniques, including early reconstructive (plastic) procedures and a variety of suturing methods. Furthermore, the treatise discusses *Bandhana Karma* (bandaging techniques), emphasizing its significance in trauma management and effective wound healing.[1,2]

The management of chronic wounds in modern medicine continues to pose a significant challenge due to factors such as infection, improper wound dressing, and limited resources. Traditional bandaging techniques described in the *Sushruta Samhita* demonstrate anatomical precision and effective use of locally available materials, aligning with present-day needs for cost-effective and sustainable healthcare practices. Revisiting these methods may offer valuable insights into developing affordable, biocompatible approaches to chronic wound care, potentially

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complementing or reducing reliance on expensive advanced materials.[3]

Sushruta's fourteen *Bandhana Karma* techniques were tailored to distinct anatomical regions and pathological conditions, highlighting an early emphasis on context-specific wound management. These principles parallel modern practices that prioritize injury-specific bandaging approaches. For instance, his detailed guidance on facial bandaging, splint application for fingers, and complex joint dressings demonstrates a nuanced understanding of wound behavior, infection control, and the importance of securing dressings according to the site and nature of the injury.[4,5]

The field of wound care has evolved significantly since the time of Sushruta, with advancements in materials such as hydrogel dressings, nanofiber-based gauzes, and silicone-derived products that offer antimicrobial properties, moisture retention, and enhanced adaptability. Despite these innovations, the use of natural materials like cotton and medicinal herbs in Sushruta's practices reflects an early emphasis on biocompatibility and environmentally conscious care. These principles align closely with contemporary priorities in healthcare that promote sustainability and reduced environmental impact[6].

Sushruta's work elucidates several principles that remain relevant in contemporary practice, including the use of natural antiseptics for infection control, appropriate pressure application in vascular wounds, and techniques aimed at minimizing scar formation. His approach also emphasized systematic, stepwise wound management, involving regular application, removal, and readjustment of dressings at defined intervals- paralleling modern postoperative care protocols[7,8]. Sushruta's approach highlights both the physiological and psychological dimensions of wound care, underscoring the importance of patient comfort and stabilization as integral components of the healing process. These principles are particularly relevant in rural and resource-limited settings, where access to advanced medical materials is constrained. Integrating Sushruta's bandaging techniques with modern innovations may enhance wound management while reducing dependence on antibiotics and synthetic dressings, thereby contributing to global efforts to address antimicrobial resistance and resource limitations[9,10].

Sushruta's contributions to wound care, especially his bandaging methods, continue to hold enduring significance in modern surgical practice. Bhattacharya[11] emphasized the historical importance of these techniques, particularly their focus on infection control and appropriate pressure application-key elements of contemporary wound management. Dev et al,[12] highlighted the adaptability of surgical procedures described in the *Sushruta Samhita* to present-day patient-centered care. Similarly, Kumar[13] noted the compatibility of Sushruta's bandaging methods with modern materials such as hydrogels and nanofibers, supporting their continued relevance. Bagde et al[14] further compared these traditional techniques with current approaches to managing chronic wounds and fractures, while Mishra[15] underscored the ongoing applicability of Sushruta's surgical principles, particularly in low-resource environments, Gupta[16] contributes for wound healing concept in Ayurveda and modern, Patil & Asutkar[17] describes potential of potential of Sushruta's techniques into integrative surgical practice.

Table 1: Key contributions and modern corelation of Sushruta's bandaging techniques[11-17]

Authors (years)	Key findings	Research focus	Limitations	Future scope
Bhattacharya S (2012)	Highlighted the importance of infection control and pressure modulation in optimizing wound healing outcomes.	Clinical relevance of classical wound care principles described by Sushruta.	Absence of direct comparative trials with modern wound care protocols.	Integration of Ayurvedic wound principles with evidence-based dressing technologies.
S Dev S.et al. (2015)	Demonstrated that Sushruta's surgical and bandaging principles align with modern patient-centred care approaches.	Evaluation of ancient surgical wisdom in contemporary wound management	Limited translation into practical, standardized clinical applications.	Adaptation of traditional methods in low-resource and rural healthcare settings.
Bagde et al. (2018)	Reported similarities between Sushruta's techniques and modern fracture and ulcer	Comparative study of ancient versus modern wound care	Limited generalizability across diverse wound etiologies	Expansion into chronic wound management and multidisciplinary care models.

	management practices.	techniques.	and patient populations.	
Mishra B (2020)	Emphasized the continued relevance of Sushruta's techniques, especially in underserved and rural populations.	Evolution and sustainability of surgical knowledge systems.	Insufficient contemporary comparative datasets and clinical trials.	Integration of traditional methods with modern surgical technologies in developing regions.
Kumar A (2021)	Established correlation between Sushruta's bandaging methods and advanced materials like nanofiber and hydrogel dressings.	Comparative analysis of traditional and modern biomaterial-based dressings.	Lack of robust experimental and clinical validation studies.	Development of biodegradable and bioactive dressings inspired by Ayurvedic concepts.
Gupta V et al. (2022)	Suggested that Sushruta's bandaging principles optimize moisture balance similar to modern moist wound healing concepts.	Physiological basis of wound healing environments.	Limited mechanistic studies validating moisture-retention properties.	Development of Ayurvedic-inspired moisture-retentive dressings.
Patil S &Asutkar S (2023)	Highlighted translational potential of Sushruta's techniques into integrative surgical practice.	Bridging traditional knowledge with modern surgical science.	Need for interdisciplinary validation and standardization.	Creation of integrative wound care protocols combining Ayurveda and modern medicine.

These studies together highlight the practical value of ancient surgical wisdom and its continued relevance in modern times, particularly in the treatment of wounds, infections, and sustainable healthcare practices. The alignment between Sushruta's approaches and contemporary non-invasive treatments opens the door for integrative healthcare solutions that draw from a variety of medical traditions.

MATERIALS AND METHODS

Data Identification

Relevant literature on Sushruta's wound care practices was sourced from ancient medical texts, scholarly journals, and modern research databases.

Data Collection

Appropriate articles, books, and research studies focusing on Sushruta's methods and their present-day applications were selected for review.

Data Analysis

Key findings, challenges, and potential applications were extracted from each source to facilitate a comparison between traditional practices and modern wound care approaches.

Data Synthesis

The collected information was organized and categorized based on its relevance to contemporary wound management, with particular attention to adapting Sushruta's techniques for current clinical use.

RESULT

Historical Context of Bandaging Techniques in Sushruta Samhita

Sushruta Samhita, authored by Sushruta, is regarded as one of the earliest comprehensive works on medical science, earning him the title "Father of Surgery." This classical text presents a systematic approach to surgical practices, including detailed descriptions of bandaging techniques, referred to as *Bandhana Karma*. These methods were vital in trauma management, post-surgical care, and the treatment of chronic wounds. Within Ayurveda, bandaging formed an integral component of *Shalya Tantra* (surgery), as it promoted effective wound healing and helped prevent complications[18].

Development of Bandaging Practices

Sushruta described the use of bandaging as a fundamental method for stabilizing injuries, controlling hemorrhage, and preventing infection. His detailed classification of fourteen *Bandhana Karma* techniques reflects a sophisticated understanding of human anatomy and the interaction between bandaging materials and the body's healing processes. In ancient practice, bandages served multiple purposes, including immobilizing affected areas, protecting wounds, and facilitating the application and retention of medicinal substances.

Beyond their physical role, Sushruta's bandaging methods also addressed patient comfort by

reducing pain and allowing functional movement wherever possible. These approaches demonstrate early foundations of modern ergonomic and patient-centered care principles[19,20].

Contemporary and Global Significance

The influence of Sushruta Samhita is evident in modern wound management practices worldwide. Techniques such as compression therapy, commonly used for conditions like venous ulcers, reflect principles similar to Sushruta's concept of optimal bandaging (*Bandha*).

His recommendations- such as avoiding knots directly over wound sites and adjusting the tightness of bandages according to different anatomical regions- continue to align with current surgical standards. These enduring principles highlight the global relevance and lasting impact of his contributions to medical science[21,22].

Table 2: Key historical insights and their modern corelations

Clinical Insights	Modern Interpretation	Clinical Application in contemporary practice
Avoidance of knots directly over wounds.	Use of pressure-free and atraumatic dressing techniques.	Minimizes localized ischemia, reduces pain, and prevents tissue necrosis; improves patient comfort and healing outcomes.
Regulation of bandage tightness based on site and pathology.	Graduated compression therapy and tailored pressure bandaging.	Essential in management of venous ulcers, lymphedema, and edema control; enhances venous return and lymphatic drainage.
Natural fibers such as cotton and silk	Biocompatible and non-reactive dressing materials (e.g., gauze, cotton-based dressings)	Promotes wound healing, reduces infection risk, and ensures better tissue compatibility.
Selection of bandage type based on anatomical location.	Anatomically contoured and function-specific dressings.	Provides stability, prevents displacement, and improves functional recovery.
Use of medicated dressings (herbal applications)	Medicated and bioactive dressings (antimicrobial, hydrogel, alginate)	Enhances healing through anti-inflammatory, antimicrobial, and regenerative properties.

Legend: The table presents an overview of classical bandaging principles described by Sushruta and their corresponding applications in modern clinical practice.

Comprehensive Overview of Sushruta's Fourteen Bandaging Techniques

The fourteen *Bandhana Karma* (bandaging techniques) described in the Sushruta Samhita represent a highly specialized aspect of ancient Indian medical practice. Developed by Sushruta, these methods were grounded in a detailed understanding of human anatomy, biomechanics, and the body's natural healing mechanisms.

Each technique was carefully designed for specific types of injuries, anatomical locations, and pathological conditions. Their primary objectives were to provide stability, protect the affected area, and promote efficient healing. This systematic approach highlights the advanced and practical nature of surgical care in early medical traditions[23].

Anatomical Precision and Functional Effectiveness

Sushruta categorized bandaging techniques based on their shape, site of application, and the nature of the injury being treated. This classification ensured that each bandage served a precise mechanical and therapeutic purpose, aiding both pain reduction and physiological recovery. For instance, *Kosha Bandha* was used to support and immobilize fingers and thumbs in cases such as fractures, while *Swastika Bandha* (figure-eight bandage) provided stability to joints like the knees and elbows[24].

Importantly, Sushruta emphasized the need to avoid excessive tightness that could impair circulation or cause discomfort- an idea consistent with modern concerns about ischemia. His methods aimed to preserve anatomical alignment, allow necessary movement, and minimize the risk of further injury, principles that remain fundamental in contemporary wound care and bandaging practices.

Continuity of Bandaging Principles in Modern Practice

Contemporary medical practice continues to reflect many of the principles originally outlined in the Sushruta Samhita by Sushruta. Several commonly used bandaging techniques closely parallel the traditional *Bandhana Karma* methods.

For example, the figure-eight bandage is widely applied in the management of sprains to provide joint support, the spiral bandage is used for dressing cylindrical body parts such as limbs, and the circular

bandage helps secure primary dressings effectively[25,26].

Table 3: Sushruta's 14 *Bandhana karma* and their modern corelations

***Bandhana karma* (Ayurvedic name)**	**Modern equivalent**	**Application /Uses**
Kosa bandha	Finger splint	Stabilization of fractures and dislocations of fingers and thumb.
Dama bandha	Spica bandage	Used for narrow anatomical regions such as genitalia.
Swastika bandha	Figure-of-eight bandage	Support for joints including knee, elbow, and wrist.
Anuvellita bandha	Spiral bandage	Applied over cylindrical structures like arms and legs.
Mutoli bandha /Pratoli bandha	Circular bandage	Suitable for neck and other cylindrical body parts.
Mandala bandha	Spiral-reverse bandage	Used for conical or cylindrical areas such as arms and thighs.
Sthagika bandha	Recurrent stump bandage	Applied to distal extremities such as fingers and toes.
Yamaka bandha	Immobilization bandage (Buddy taping)	Stabilization in adjacent fractures or injuries.
Khatwa bandha	Four-tailed bandage	Indicated for jaw, cheek, and facial injuries.
China bandha	Eye patch	Protection and management of ocular injuries.
Vibandha bandha	Abdominal bandage	Used in abdominal wounds and postoperative care.
Vitana bandha	Capeline bandage	Applied in head injuries.
Gophana bandha	Chin/Barrel bandage	Used for chin, nose, lips, and shoulder regions.
Panchangi bandha	Sling bandaging	Provides support and suspension for upper limb injuries.

This table illustrates the classical bandaging techniques described by Sushruta, correlating them with their modern equivalents and highlighting their practical clinical applications in contemporary surgical practice.

Bandaging Materials: Traditional Foundations and Modern Parallels

Material selection was considered a crucial aspect of *Bandhana Karma* in the Sushruta Samhita by Sushruta, as it directly influenced the effectiveness of wound healing and the prevention of complications. Sushruta emphasized choosing appropriate materials to ensure comfort, protection, and optimal recovery outcomes.

He classified bandaging materials according to their properties, such as texture, flexibility, absorbency, and compatibility with the human body. Commonly used materials in ancient practice included cotton, tree bark, silk, and leather. This classification reflects an advanced understanding of biocompatibility and wound dynamics.

Notably, these considerations remain highly relevant in modern medicine, where similar principles guide the selection of dressing materials to promote safe and efficient healing[27].

Traditional Materials for Wound Dressing

Ancient wound care practices described in the Sushruta Samhita by Sushruta utilized a variety of natural materials selected for their specific therapeutic properties:

- ***Karpasa* (cotton):** A soft, highly absorbent, and breathable material used to dress wounds and absorb exudates, providing comfort while minimizing irritation.
- **Bark:** Rigid and durable, bark was employed where structural support was required, similar to modern splinting techniques or plaster applications.
- **Silk:** Due to its smooth texture, silk was applied to sensitive areas to reduce friction and prevent further tissue damage.
- **Leather and wool:** These materials offered strength and elasticity, making them suitable for compression and immobilization in more demanding bandaging applications[28].

Modern Equivalents of Traditional Material

In contemporary medicine, advanced synthetic materials have been developed to replicate and enhance the properties of traditional dressings. These

include hydrogels, nanofiber-based materials, and silicone dressings. Compared to their ancient counterparts, they provide improved moisture regulation, antimicrobial protection, and controlled elasticity, leading to more efficient wound healing outcomes[29].

Integration of Ancient Concepts with Modern Materials

- Modern wound care materials reflect the same functional principles observed in traditional practices:
- **Hydrogels:** These maintain a moist wound environment, similar to the absorbent and moisture-retentive properties of cotton, making them particularly useful for chronic wounds.
- **Nanofibers:** Designed to mimic the breathability and adaptability of silk, while offering enhanced antimicrobial capabilities.
- **Biodegradable polymer bandages:** These act as environmentally friendly alternatives to rigid materials like bark, while providing improved flexibility and strength.
- Together, these advancements demonstrate how ancient insights continue to inform and shape modern innovations in wound management, as summarized in Table 4[30,31].

Table 4: Traditional and modern materials in bandaging

Ancient material	Modern counterpart	Key properties
Cotton *(Karpasa)*	Sterile gauze, hydrogel dressings	Soft texture, high absorbency, allows aeration.
Bark	Biodegradable polymers	Provides structural support; environmentally sustainable.
Silk	Nanofiber-based dressings	Smooth surface; minimizes friction and tissue irritation.
Leather	Elastic bandages, compression wraps	Flexible and long-lasting; offers firm support.
Wool	Foam-based dressings	Thermal insulation with good absorptive capacity.
Metal strips	Rigid splints and supports	Ensures immobilization and stabilization.
Medicinal herbs	Antimicrobial dressings	Prevents infection and promotes wound healing.
Plant fibres	Biodegradable mesh dressings	Eco-friendly and absorbent in nature.
Alabu	Foam pads, cushioned dressings	Provides protection and cushioning effect.
Plant bark adhesives	Adhesive dressings	Helps in securing and retaining wound coverings.

Comparison of traditional Ayurvedic materials and their modern equivalents, highlighting key properties relevant to wound care.

Importance of Choosing Appropriate Materials

Sushruta emphasized that selecting the right materials is essential for achieving an effective balance between patient comfort, healing performance, and practical usability. His observations focused on characteristics such as texture, flexibility, and therapeutic value- factors that closely resemble modern criteria used in the selection of wound dressing materials[32].

Today, these foundational ideas have evolved into advanced approaches for designing wound care products that aim to maximize healing while minimizing environmental impact. Modern researchers and healthcare professionals continue to draw inspiration from Sushruta's methods, using them as a basis for developing innovative materials suited to a wide range of medical applications[33].

Bandaging Techniques in Traumatic and Non-Traumatic Wound Care

Sushruta described bandaging practices, known as *Bandhana Karma* in the Sushruta Samhita, as essential for proper wound coverage and management. These methods address not only acute traumatic injuries but also long-standing chronic wounds. His techniques are guided by principles of anatomical accuracy, ensuring functional support, and promoting a holistic approach to healing various injuries and medical conditions[34].

Bandaging in Trauma Wound Management

Kosha Bandha (splint bandage) and *Swastika Bandha* (figure-eight bandage) were appropriately used in the management of traumatic wounds such as fractures, dislocations, and cuts. These techniques helped immobilize the injured parts, thereby reducing pain, preventing complications arising from improper alignment, and lowering the risk of secondary infections.

Bandaging for Major Trauma and Non-Trauma Conditions

Bandaging in Major Trauma

Kosha Bandha was used for stabilizing fractures of the fingers and other small joints, with splinting methods comparable to those used in modern practice. *Mandal Bandha* was applied to cylindrical body parts such as the arms and legs, functioning similarly to a contemporary cast.

Principles of Bandaging

Sushruta emphasized that bandages should be firm yet not restrictive, ensuring that blood circulation was not impaired. This aligns with the modern concept of compression bandaging, commonly used in the management of acute injuries like sprains and strains.

Bandaging in Non-Trauma Conditions

In the treatment of chronic wounds, bandages were carefully applied to avoid infection, while promoting healing and providing comfort to the patient. *Bibandha Karma* (abdominal bandaging) was used in non-traumatic conditions such as hernia to support and maintain the shape of the abdomen, as well as to aid recovery following surgery[36].

Bandaging in Non-Trauma Scenarios

In non-trauma conditions, critical applications of bandaging included the management of diabetic wounds and venous ulcers. Diabetic wounds were treated with loose, absorbent bandages to protect delicate skin from friction, while venous ulcers required firm bandaging to improve blood circulation and reduce swelling.

Table 5: Role of bandaging in traumatic and non-traumatic wound care

Application type	*Bandhana karma*	Modern equivalent	Benefits
Fractures	*Kosha bandha*	Splint bandage	Provides immobilization and stabilizes fractured bones.
Joint injuries	*Swastika bandha*	Figure of 8 bandage	Ensures joint stability while allowing controlled movement.
Chronic ulcers	*Gophana bandha*	Barrel bandage	Offers protection and cushioning to the affected area.
Venous ulcers	*Mandala bandha*	Compression bandage	Enhances venous return and reduces edema.
Abdominal wounds	*Bibandha bandha*	Abdominal binder	Supports postoperative healing and maintains abdominal integrity.
Ocular injuries	*China bandha*	Eye patch	Protects the eye and facilitates healing.

This comparison highlights the parallels between classical Ayurvedic bandaging techniques and their modern counterparts. The principles described by Sushruta continue to inform contemporary wound care, particularly in areas such as infection control, scar prevention, and long-term wound management.

Innovations Founded on Tradition

Many modern practices, such as compression wraps for venous ulcers and adhesive dressings for surgical wounds, are rooted in the principles described by Sushruta. His focus on proper anatomical fit and the avoidance of excessive pressure on sensitive areas closely corresponds with contemporary wound care protocols[37,38].

Innovations in Bandaging: From Sushruta to Modern Biocompatible Materials

The evolution from traditional bandaging methods to the use of modern biocompatible materials highlights the lasting relevance of Sushruta's principles. Earlier materials like *Karpasa* (cotton) and tree bark were effective in their time, but advancements in medical science have introduced new materials that offer improved functionality and enhanced healing properties[39].

Evolution from Traditional to Modern Bandaging Practices

Sushruta's *Daam Bandha* (spica bandage), traditionally used for narrow regions such as the genital area, has evolved into modern elastic polymer compression garments. Similarly, *Mandal Bandha* (spiral bandage), used for cylindrical body parts, has been adapted into stretchable synthetic wraps that provide better flexibility and support.

Advancements in material science have further expanded wound care options. Hydrogels, for example, maintain moisture at the wound site similar to cotton, while also providing a cooling effect that supports healing. Antimicrobial nanofiber dressings reflect the concept of herbal-infused bandages described by Sushruta, emphasizing infection control through natural or bioactive agents. In addition, silver-infused dressings align with Ayurvedic practices that utilized antimicrobial metals, offering effective long-term protection against infection[40].

Biocompatibility and Sustainability

In line with contemporary concerns for biocompatibility and environmental sustainability, Sushruta emphasized the use of natural materials in medical care. Modern alternatives, such as biodegradable polymers and plant-based adhesives, have replaced many traditional materials while maintaining effectiveness. These innovations not only ensure patient safety but also reduce the environmental impact of medical interventions, continuing the principle of safe and sustainable healing practices[41].

Sophisticated Applications

Modern biocompatible bandages are equipped with advanced technologies such as drug delivery systems and pH sensors to enhance wound care. These innovations have conceptual parallels with Sushruta's use of medicated bandages infused with healing herbs in ancient times. Today, such smart bandages enable real-time monitoring of the wound environment and deliver targeted therapy to support effective and precise healing, as presented in Table 6[42,43].

Table 6: Sushruta inspired innovations in modern wound care

Traditional practice	Contemporary innovation	Silent features
Cotton *(Karpasa)* dressings	Hydrogel-based dressings	Maintain moisture balance and provide a cooling effect
Herbal impregnated bandages	Antimicrobial dressings	Effective prevention and control of wound infections
Bark splints	Biodegradable polymer splints	Environment-friendly with adequate structural support
Metallic strips	Silver-impregnated dressings	Broad-spectrum antimicrobial activity
Medicated bandages	Controlled drug delivery systems	Targeted and sustained therapeutic action
Spiral bandages	Elastic compression wraps	Flexible, adjustable, and provide uniform compression

The principles described by Sushruta continue to influence modern biomaterial development, integrating traditional knowledge with advancements in material science. This evolution enhances wound care outcomes in terms of antimicrobial resistance, sustainability, and cost-efficiency.

Comparison of Ayurvedic and Modern Principles in Wound Healing

The Sushruta Samhita provides detailed insights into wound healing principles that closely parallel modern medical concepts. Ayurveda emphasizes natural healing processes through *Shodhana* (cleansing) and *Ropana* (healing), while contemporary medicine employs techniques such as debridement, antiseptics, and antibiotics. Despite differences in approach, both systems prioritize infection control, tissue regeneration, and the creation of an optimal environment for wound healing[44].

Debridement and Infection Control

In Ayurveda, wound cleansing is achieved through medicated oils *(Taila)* and herbal decoctions with antimicrobial properties. Similarly, modern medicine uses antiseptic agents such as iodine and hydrogen peroxide for disinfection. Sushruta's use of alkaline *Kshara*, a caustic substance for wound purification, is comparable to the concept of surgical debridement used in present-day clinical practice[45].

Wound Healing and Tissue Regeneration

Sushruta recommended *Ropana Dravyas* like honey and ghee, valued for their antimicrobial and anti-inflammatory effects in promoting healing. In modern wound care, advanced dressings such as silver-impregnated materials and hydrogels replicate these functions by maintaining a moist, microbe-free environment that supports cell growth and tissue regeneration, as outlined in Table 7[44,45].

Table 7: Comparison of Ayurvedic and modern wound healing principles

Ayurvedic principle	Modern equivalent	Application / Use
Shodhana [cleansing]	Debridement and antiseptic techniques.	Elimination of necrotic tissue and infection control.
Ropana [healing]	Antimicrobial dressings and hydrogel therapy.	Facilitates tissue repair and regeneration.
Kshara [alkaline cleansing]	Surgical debridement	Cleansing and sterilization of wound bed.

Medicated oil *[Taila]*	Antibiotic ointments	Reduces infection and promotes soothing effect.
Seevana karma [suturing]	Sutures and surgical staples	Ensures effective wound closure.
Herbal pain relievers	Modern analgesic drugs	Alleviates pain and improves patient comfort.

Contemporary wound management strategies are deeply rooted in classical Ayurvedic concepts, with modern techniques enhancing their precision and efficacy while preserving the fundamental principles of wound care.

Integration of *Anushastra Karma* (Non-Surgical Tools) in Wound Management

The Sushruta Samhita describes various *Anushastra Karma*, or non-surgical tools, along with innovative techniques such as *Kshara Sutra* therapy and herbal applications. These methods were developed for the management of conditions requiring minimal invasiveness, including chronic fistulas, abscesses, and non-healing wounds. They reflect an early understanding of conservative yet effective therapeutic interventions[46].

***Kshara Sutra*: Revolutionary Non-Surgical Technique**

Kshara Sutra is a medicated thread coated with alkaline herbal preparations, traditionally used in Ayurveda for the treatment of *Bhagandara* (anal fistula). This technique remains in clinical use today. Its modern parallel can be seen in catheter-based drug delivery systems, which provide sustained and localized release of medication directly at the affected site[47].

Case Applications of Sushruta's Bandaging Techniques in Modern Medicine

The continued relevance of Sushruta's bandaging methods is evident in their application within modern clinical practice. *Gophana Bandha* (chin or barrel bandage), for instance, has shown effectiveness in managing pressure ulcers and diabetic wounds, highlighting the adaptability of these ancient techniques.

Venous Ulcers

Mandal Bandha, or spiral bandaging, has influenced the development of compression wraps used in venous ulcer management. These modern applications help control oedema and enhance circulation, thereby promoting faster healing.

Diabetic Wounds

The use of multi-layer dressings in modern wound care reflects Sushruta's concept of layered bandaging. This approach assists in infection control, absorption of wound exudate, and cushioning of the affected area, ensuring comprehensive wound management[48].

Surgical and Non-Surgical Approaches to Chronic Wounds in Ayurveda

Sushruta adopted a combined approach involving *Chedana* (surgical excision) and *Bandhana Karma* (bandaging) for the holistic management of wounds. His methods were designed to effectively address both acute and chronic conditions while minimizing complications and promoting safe, structured healing.

Surgical Methods

Sushruta's use of *Chedana* (excision) for removing dead or damaged tissue is comparable to modern surgical debridement techniques. His precise approach ensured that vital structures, known as *Marma*, were not harmed, thereby reducing complications and supporting smoother recovery.

Non-Surgical Methods

Non-surgical approaches included the use of herbal-infused bandages and *Pichu* (medicated plugs) to control infection and promote healing. These methods closely resemble modern treatments such as antibiotic ointments and hydrocolloid dressings, which provide protection, maintain moisture, and support tissue repair[49,50].

Table 8: Surgical and non-surgical approaches

Approach (Ayurvedic term)	Modern equivalent	Key benefits
Chedana	Surgical debridement	Removes necrotic tissue
Kshara sutra	Drug infused catheters	Sustained medication delivery
Pichu and *Patra* [cotton/leaves]	Hydrocolloid dressings	Absorbent infection control
Taila [medicated oils]	Antibiotic ointments	Reduces infection and inflammation
Anuloma sutra [tying threads]	Surgical threads	Holds tissue together
Bandhana karma [bandaging]	Compression and protective wraps	Stabilises wound

A comparative overview of Ayurvedic surgical and non-surgical approaches alongside their modern equivalents, emphasizing their key advantages in wound management.

Future Directions and Limitations

Sushruta's bandaging techniques *(Bandhana Karma)* offer significant potential for integration with modern medical technologies, opening new avenues for innovation in wound care. By combining ancient principles with advanced research, there is scope to develop holistic, sustainable, and cost-effective solutions for both acute and chronic wounds. Such integration can also help address global challenges, including antimicrobial resistance, limited healthcare access in low-resource settings, and environmental concerns[51].

Challenges and Limitations

Despite their promise, the application of Sushruta's techniques in modern medicine requires rigorous clinical validation to ensure widespread acceptance as evidence-based practices. Additionally, implementing advanced technologies inspired by these principles, such as AI-enabled bandages, remains challenging in rural and resource-limited areas. Nevertheless, blending traditional knowledge with modern innovations presents opportunities to create accessible and effective solutions for global healthcare disparities[52].

DISCUSSION

The Sushruta Samhita, one of the oldest known medical texts, continues to serve as a foundational source of knowledge in Ayurveda, particularly in surgery and wound management. Its relevance persists in modern medicine, especially in the application of bandaging techniques *(Bandhana Karma)* across trauma and non-trauma care, material science advancements, and holistic patient management[53].

Relevance of Sushruta's Bandaging Techniques

Sushruta's fourteen bandaging techniques were designed to address specific anatomical and pathological conditions. For instance, *Swastika Bandha* for joints aligns with modern orthopedic practices, while *Mandal Bandha* resembles spiral compression therapy used for venous ulcers. These methods reflect a deep understanding of biomechanics, wound stability, pressure control, and infection prevention[54]. They also emphasize patient comfort and psychological well-being, aligning with the modern shift toward personalized and holistic care. Their applications extend to chronic ulcers, fractures, and post-surgical wounds, focusing on minimizing pain while providing functional support[55].

Modern Innovations and Traditional Materials

Sushruta's use of natural materials such as cotton *(Karpasa),* silk, and bark highlights an early emphasis on biocompatibility and sustainability. Modern equivalents, including hydrogel dressings and nanofiber-based materials, enhance these properties by improving moisture retention, antimicrobial action, and biodegradability. This convergence of traditional material use and modern innovation represents a broader integrative approach to medicine[56]. Furthermore, advancements in nanotechnology- such as combining Ayurvedic herbs like turmeric and neem with nanofiber dressings- offer promising outcomes, including sustained antimicrobial effects, faster healing, and reduced inflammation. This mirrors Sushruta's concept of medicated bandages, where protection and treatment were integrated into a single therapeutic approach[57].

Chronic Wounds

Sushruta's bandaging techniques are not limited to the management of traumatic injuries; they also have relevance in non-traumatic and long-standing conditions such as diabetic ulcers and venous insufficiency. Contemporary healthcare systems often face challenges in treating chronic wounds due to persistent infection, delayed healing, and rising antibiotic resistance. In this context, Sushruta's principles- particularly individualized bandaging methods and the use of medicated dressings- provide a structured and potentially sustainable approach that is also patient-friendly for managing such complex wound conditions[58].

The medical texts authored by Sushruta present enduring principles of wound care and bandaging that remain relevant even in modern clinical practice. His 14 bandaging techniques, known as *Bandhana Karma*, are specifically designed according to different types of injuries and anatomical regions, reflecting a deep understanding of biomechanics, healing processes, and patient comfort. The use of biocompatible materials such as cotton, *Karpasa*, and bark also aligns with current trends toward sustainable and environmentally conscious medical practices.

Sushruta's methods further demonstrate potential for integration with modern innovations, including hydrogels, nanotechnology, and AI-assisted bandaging systems, while preserving the essence of Ayurvedic knowledge. These approaches can contribute to addressing key challenges in wound management, such as infection control, chronic wound care, and resource limitations, particularly in underserved regions.

However, the application of these traditional techniques in contemporary healthcare is constrained by the lack of extensive clinical validation and limited scalability. Addressing these gaps requires collaborative and interdisciplinary research to scientifically evaluate and refine these practices. Such efforts could bridge traditional wisdom with modern

medical science to develop more effective integrative healthcare solutions.

Limitations

A major limitation of this work is the lack of direct clinical evidence supporting the integration of Sushruta's bandaging techniques with modern wound care practices. While theoretical analysis suggests meaningful parallels between ancient and contemporary methods, the absence of empirical studies or clinical trials prevents definitive validation of their effectiveness in real-world healthcare settings. Therefore, further systematic research and clinical investigations are required to establish the practical efficacy and applicability of combining Sushruta's techniques with current wound management technologies.

CONCLUSION

In conclusion, Sushruta's legacy offers a foundation for sustainable, holistic, and patient-centered wound care. Integrating his insights with advanced medical technologies has the potential to strengthen healthcare systems globally, addressing present and future challenges while preserving the core principles of Ayurvedic medicine.

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