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Review

Modern Hemostatic Sponges for Parenchymal Bleeding: Composition, Mechanisms of Action, and Clinical Effectiveness. A Literature Review

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Abstract

Parenchymal bleeding arising from injuries to the liver, spleen, and kidneys represents one of the most challenging types of hemorrhage to control due to its diffuse nature, absence of a clear bleeding point, and the high likelihood of coagulopathy. Despite the widespread use of mechanical hemostasis, electrocoagulation, and packing techniques, their effectiveness remains limited in deep or multifocal parenchymal injuries. Consequently, the use of topical hemostatic sponges of various types has gained increasing relevance in both emergency and elective surgery. The aim of the study is to evaluate the effectiveness of hemostatic sponges in the management of parenchymal bleeding by analyzing preclinical and clinical studies focused on different categories of topical hemostatic materials. A comprehensive review of preclinical and clinical studies, systematic reviews, and meta-analyses evaluating hemostatic sponges of animal, plant, and synthetic origin for parenchymal bleeding was conducted. Searches were performed in PubMed, MedLine, and Scopus for the period 2019-2025. A total of 213 publications were identified; 119 were excluded based on predefined criteria (duplication, insufficient level of evidence, absence of data on parenchymal organs). Ninety-four studies meeting the inclusion criteria were included in the final analysis. Most studies demonstrate that the use of topical hemostatic sponges significantly reduces the time to bleeding control, decreases intraoperative blood loss, and lowers the risk of rebleeding compared with standard hemostatic techniques. The most extensively investigated materials include collagen, gelatin, oxidized cellulose, fibrin,

and chitosan-based sponges, each characterized by distinct mechanisms of action. Comparative analyses indicate that, although many types of sponges show comparable clinical effectiveness, the optimal choice depends on wound characteristics and intraoperative conditions. wide range of hemostatic sponges is currently available for the management of parenchymal bleeding; however, no universally ideal material exists. This review confirms that topical hemostatic sponges represent a justified and clinically effective adjunct to standard approaches for achieving hemostasis.

Keywords: hemostatic sponges, topical hemostasis, parenchymal bleeding, collagen, gelatin, chitosan.

1. Introduction

Parenchymal bleeding occurring during trauma or resections of the liver, spleen, and other solid organs remains one of the major challenges in abdominal surgery and transplantology. Its complexity is determined by the friable structure of parenchymal tissue and its rich vascularization, which result in diffuse bleeding and limit the applicability of conventional vascular hemostasis techniques [1,2]. Significant intraoperative blood loss and the frequent need for massive transfusion therapy are directly associated with increased postoperative morbidity and mortality [1,3]. Against this background, topical hemostatic agents—including various types of hemostatic sponges—are increasingly used as an important adjunct to standard techniques of parenchymal hemostasis [1-4].

Over the past decades, several systematic reviews and meta-analyses have evaluated the use of topical hemostatic agents during liver surgery. It has been shown that fibrin-based and collagen-based materials (such as TachoSil, CoStasis, and others) can reduce the time required to achieve hemostasis; however, their impact on total blood loss, transfusion requirements, and postoperative complications remains debated [2,3,5]. Moreover, the number of available topical agents continues to expand, while their routine use is not always justified from the standpoint of cost-effectiveness and quality of evidence [3,5].

Simultaneously, there has been rapid development of biomaterials based on natural polymers—particularly chitosan, modified carboxymethylcellulose, and their composites—designed for managing massive and non-compressible hemorrhage, including experimental models of parenchymal liver injury [6-10]. These sponges exhibit high absorptive capacity, pronounced procoagulant activity, and additional beneficial properties such as antimicrobial effects and potential to promote tissue regeneration [7-10].

In addition to classical collagen, gelatin, and cellulose-based sponges, an increasing number of studies report on the use of thrombin-gelatin matrices (e.g., Floseal) and new composite patches and sheets (such as GATT-Patch, Stopad, and others), evaluated in randomized studies in hepatic resections [4,5,11-13]. Overall, most clinical and experimental investigations suggest high local hemostatic effectiveness of these materials; however, comparison between different types of sponges and assessment of their influence on outcomes—such as rebleeding rates, total blood loss, and postoperative complications—remain subjects of active scientific discussion [2-5,11-13].

In this context, it is essential to summarize current data on the composition, mechanisms of action, and clinical effectiveness of hemostatic sponges used in the management of parenchymal bleeding, with particular emphasis on evidence from randomized controlled trials, systematic reviews, and experimental studies conducted on parenchymal organ models.

The aim of the study is to evaluate the effectiveness of hemostatic sponges in the management of parenchymal bleeding by reviewing preclinical and clinical studies investigating topical hemostatic materials of various compositions (collagen-based, gelatin-based, cellulose-based, chitosan-based, and composite formulations).

2. Methodology

We reviewed publications indexed in PubMed, MedLine, and Scopus according to the following criteria: studies published within the last five years (2019-2025), including clinical studies (randomized controlled trials and observational research), experimental studies using animal models of parenchymal bleeding, as well as systematic reviews and meta-analyses. The following keywords were used: parenchymal bleeding, liver resection, hemostatic sponge, topical hemostatic agents, collagen sponge, gelatin sponge, chitosan sponge.

Inclusion criteria

Publication within the last five years, availability of data on topical hemostatic agents used in

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parenchymal organs or experimental parenchymal bleeding models, English language, and study design corresponding to a clinical investigation, experimental study, systematic review, or meta-analysis.

Exclusion criteria

Publications older than five years (except highly cited classical randomized studies), absence of information related to parenchymal organs, duplication of data, and low level of evidence (Figure 1).

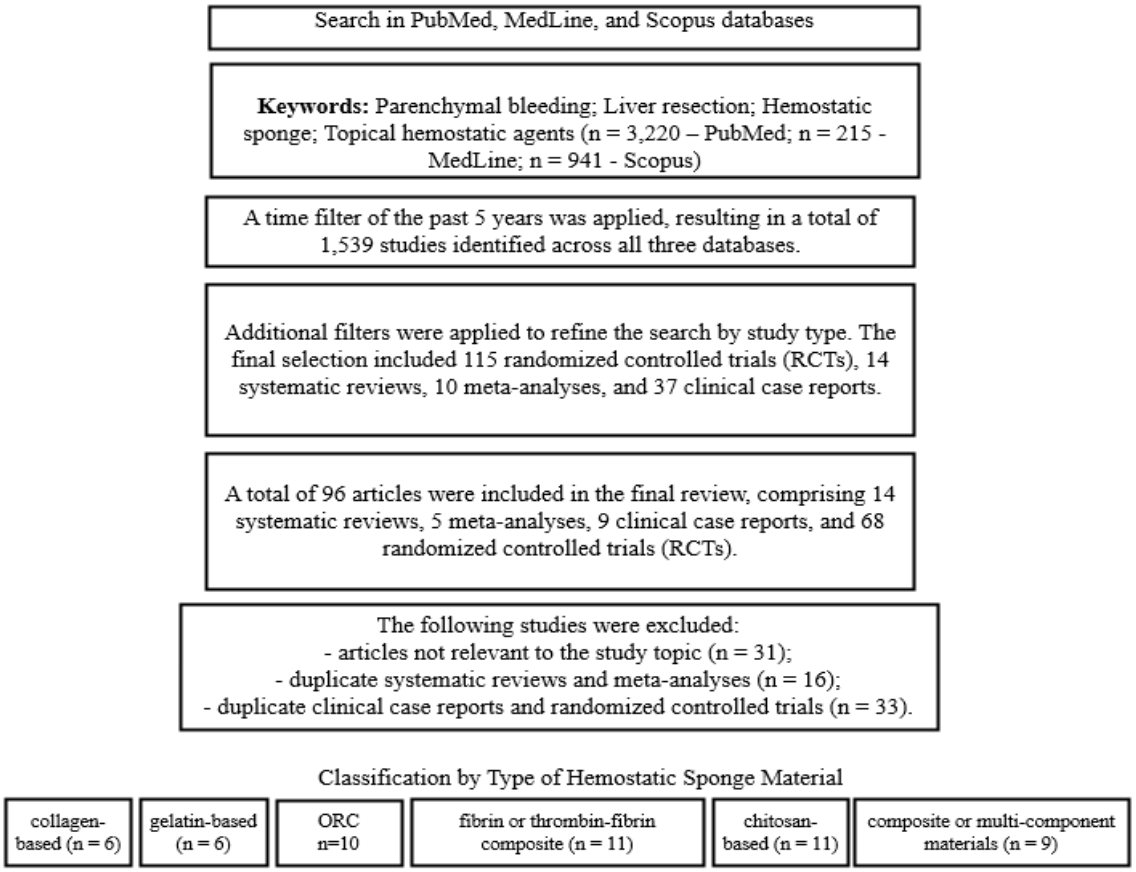

Figure 1 – Article selection algorithm

A total of 96 key sources were ultimately included in the analysis, comprising systematic reviews and meta-analyses on topical hemostatic agents in liver surgery, randomized clinical trials evaluating fibrin- and collagen-based patches and matrices, as well as experimental studies focused on the development and assessment of new sponges and composite materials based on chitosan and modified polysaccharides in models of parenchymal bleeding.

3. Results

A synthesis of the available literature indicates that the use of topical hemostatic sponges in parenchymal bleeding significantly accelerates the achievement of hemostasis and reduces intraoperative blood loss compared with standard techniques such as coagulation, suturing, and packing [14-17]. Randomized clinical trials in liver resection have shown that collagen-fibrin and composite patches decrease the duration of active parenchymal bleeding and reduce the need for additional coagulation, particularly in large or deeply located defects [16,18].

Experimental models of liver and spleen injury in animals further confirm that hemostatic sponges facilitate a more rapid establishment of stable hemostasis and improve hemodynamic stabilization compared with mechanical packing or electrocoagulation alone [19,20]. Several studies also demonstrate reductions in transfusion requirements and rebleeding rates with the use of topical hemostatic agents, although their impact on overall mortality remains less definitive and appears to depend on the severity of the initial injury and associated comorbidities [17,21].

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Importantly, the effectiveness of a particular sponge is determined not only by its chemical composition but also by pore architecture, compressibility, ability to conform closely to irregular bleeding surfaces, and persistence of contact under conditions of high blood flow [18,22].

4. Classification of Hemostatic Materials

In the literature, hemostatic materials used for the control of parenchymal bleeding are traditionally divided into three main groups: absorbable, biological, and combined agents [18,23]. Absorbable materials include collagen-based, gelatin-based, and oxidized regenerated cellulose (ORC) products, which provide predominantly mechanical and adsorptive hemostasis through swelling, defect filling, and concentration of blood cellular components at the site of injury [16,24].

Biological hemostatic agents comprise preparations containing thrombin, fibrinogen, or their combinations; they act as a local "biological glue" by forming a fibrin network directly on the wound surface, thereby accelerating the coagulation cascade [18,25].

Combined agents integrate a porous matrix (collagen, gelatin, synthetic polymer) with applied coagulation components, allowing mechanical and biochemical mechanisms of hemostasis to be unified within a single product [23,25].

Several contemporary studies also highlight a distinct group of polysaccharide-based materials—primarily those derived from chitosan and modified celluloses—which exhibit intrinsic procoagulant activity, strong adhesion to moist tissues, and additional antibacterial properties, making them particularly promising for parenchymal and non-compressible hemorrhage [19,20,26].

Such functional and structural classification facilitates comparison of different types of sponges and enables a more informed selection of materials depending on the clinical scenario and available institutional resources.

5. Requirements for Hemostatic Sponges

Contemporary studies emphasize that hemostatic sponges intended for the control of parenchymal bleeding must possess a combination of functional and biological properties that ensure rapid and sustained hemostasis. First and foremost, the material must allow immediate penetration of blood into the pore structure, initiating platelet aggregation and activation of the coagulation process. An optimal hemostatic sponge is characterized by a porous architecture with interconnected channels that facilitates simultaneous absorption of blood and uniform distribution of pressure within the defect area [27].

Another essential property is strong adhesion to the moist parenchymal surface. The liver and spleen have smooth and highly wettable surfaces, and low-adhesive materials are easily displaced by blood flow, which prevents the formation of stable hemostasis. Studies indicate that sponges with modified surfaces or increased cationic charge adhere more firmly and achieve hemostasis more rapidly [28].

Biocompatibility is an equally important requirement. The material must not induce pronounced inflammation, wound-edge necrosis, or delay tissue repair. In experimental models, biocompatibility evaluation includes the pattern of inflammatory infiltration, degree of fibrosis, and presence of residual material after resorption [29]. It has been noted that slowly degradable sponges may provoke encapsulated hematomas, abscess formation, or foreign-body reactions.

Particular attention is given to the effectiveness of hemostats under coagulopathic conditions, as patients with severe liver trauma frequently present with hemodilution, reduced levels of coagulation factors, and thrombocytopenia. In such settings, materials providing local hemostasis independent of systemic coagulation mechanisms—such as polysaccharide-based sponges or thrombin-containing compositions—are preferred [30].

Another important criterion is controlled degradation. According to current evidence, an ideal material should undergo complete resorption without forming dense capsules or disrupting the architecture of regenerating parenchyma. Both excessively rapid degradation (which may lead to rebleeding) and overly slow breakdown are undesirable [31].

To illustrate the physiological basis of local hemostasis and to substantiate the requirements for modern hemostatic materials, the review includes a schematic visualization of the key stages of the coagulation process (Figure 2). The diagram shows the sequence of events from vasoconstriction and primary platelet aggregation to activation of the intrinsic, extrinsic, and common pathways, followed by the formation of a stabilized fibrin scaffold.

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This schematic representation enables identification of the specific coagulation stage targeted by different classes of hemostatic sponges: some enhance the contact phase and platelet adhesion, others accelerate erythrocyte-polymer aggregation, and still others serve as carriers for fibrin sealant components or create a mechanical barrier over the parenchymal surface [32].

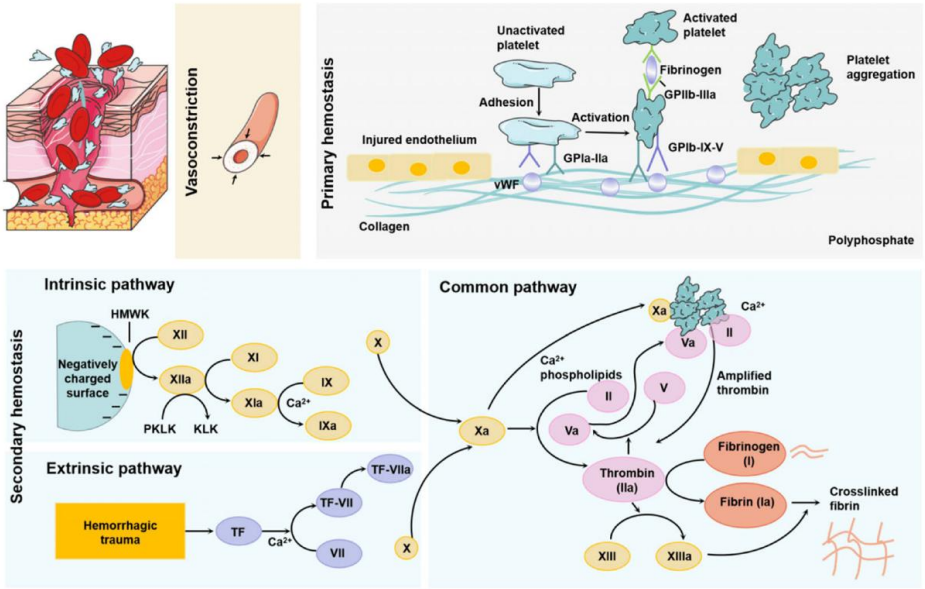

Figure 2 – Main phases of primary and secondary hemostasis: vasoconstriction, platelet activation, intrinsic and extrinsic coagulation pathways, and formation of a stabilized fibrin clot. Reproduced from Du et al. [23]

Thus, the combination of mechanical, biological, and functional requirements determines the clinical suitability of hemostatic sponges and enables the selection of optimal materials for liver surgery and other parenchymal organ interventions (Table 1).

Table 1 – Comparative mechanisms of action of different types of hemostatic sponges

Sponge type	Molecular mechanism	Cellular mechanism	Physicochemical mechanism	Additional effects
ORC	Local acidification of the environment (pH 2.5–3.0); activation of the extrinsic pathway of hemostasis; protein denaturation and acceleration of fibrin formation	Platelet adhesion and aggregation on ORC fibers; accelerated aggregation in an acidic environment	Gelatinization upon contact with blood; high sorption capacity; formation of an acidic gel film	Antimicrobial effect of low pH; barrier function
Fibrin / thrombin-based sponges	Exogenous thrombin → instantaneous conversion of fibrinogen to fibrin; activation of factor XIII; rapid completion of the coagulation cascade	Entrapment of platelets within the fibrin scaffold; stabilization of the platelet aggregate	Rapid swelling; filling of the wound defect; dense fibrin "seal effect"	Effective under coagulopathy; minimal mechanical load on tissues
Chitosan sponges	Cation-induced erythrocyte aggregation; activation of the contact pathway (factor XII); formation of a chitosan–erythrocyte gel	Binding of platelets to cationic groups; accelerated aggregation of blood cellular elements	Intensive plasma absorption; local hemoconcentration; formation of a dense, stable gel	Antibacterial activity; modifiability for functional enhancement
Composite biopolysaccharide sponges	Synergy of cationic and anionic polymers; local concentration of coagulation factors; formation of a mixed polysaccharide gel	Enhanced erythrocyte aggregation; platelet entrapment within a	Rapid capillary impregnation; optimal swelling; high strength and shear resistance	Antibacterial effect; controlled degradation; potential loading of growth factors/antibiotics

	multicomponent framework

6. Collagen Hemostatic Sponges

Collagen sponges belong to absorbable hemostatic materials and are typically porous three-dimensional matrices composed of type I collagen derived from bovine, porcine, or fish tissues, or from recombinant "human-like" collagen. The structure of such sponges is formed by preparing an aqueous collagen suspension, inducing gelation, and subsequently performing lyophilization, which results in a well-developed network of interconnected pores and a high specific surface area. By adjusting collagen concentration, freezing rate, and drying conditions, it is possible to achieve the desired density, porosity, and mechanical strength, while chemical or physical crosslinking (e.g., carbodiimide crosslinking, UV irradiation) allows stabilization of the scaffold and control over degradation rate [33].

Modern developments include recombinant collagen sponges with more uniform morphology and reproducible properties, as well as composite materials in which collagen is combined with other polymers (alginate, chitosan, polysaccharides), thereby improving water absorption, adhesion, and mechanical stability under high blood flow. Several studies have demonstrated that fish-derived collagen (for example, from tilapia skin) enables fabrication of highly absorbent sponges with high porosity and rapid blood uptake while maintaining biocompatibility and complete in vivo biodegradation [34].

The hemostatic mechanism of collagen sponges is based on a combination of mechanical and biological components. Their porous structure provides rapid blood absorption and partial tamponade of the defect, increases the local concentration of blood cells and coagulation factors within the pores, and promotes clot formation. A key role is played by the specific interaction of collagen with platelet receptors—primarily GPVI and integrin $\alpha 2\beta 1$—which mediates platelet adhesion to the collagen matrix, activation, granule release, and expression of a procoagulant surface that initiates the coagulation cascade [35].

The layer of activated platelets and fibrin polymer formed on the surface of the sponge produces a stable clot anchored within the pores. Thus, the collagen sponge serves simultaneously as a structural scaffold for the formation of a platelet-fibrin thrombus and as an active stimulator of endogenous hemostasis. It has been shown that an optimal combination of hydrophilicity, porosity, and collagen content reduces time to hemostasis and increases clot stability compared with less porous or more hydrophobic materials. Collagen sponges manufactured from recombinant or modified collagen additionally exhibit improved biodegradation, a more predictable resorption profile, and a reduced risk of immune reactions, which is considered an important advantage for use in parenchymal bleeding [36].

An experimental study by Chang et al. demonstrated that composite materials based on polyester and hydrolyzed collagen exhibit a more pronounced hemostatic effect compared with traditional polyester dressings [28]. The authors noted that even a low collagen content (approximately 1%) significantly reduced bleeding time, which they attributed to enhanced platelet activation on the composite fiber surface. Furthermore, these dressings retained the hydrophobicity of polyester—reducing the risk of adherence to the wound—while simultaneously promoting angiogenesis and granulation in a rat wound-defect model.

In a study published in the International Journal of Biological Macromolecules, Yang et al. developed a methacrylated collagen sponge with aligned channels produced by directional freeze-drying [29]. Incorporation of methacrylated hyaluronate markedly enhanced mechanical strength and the sponge's ability to rapidly recover its shape after compression, a feature critical for application in deep and non-compressible wounds. The authors showed that the material achieved significantly faster hemostasis than commercial collagen sponges due to accelerated blood penetration into the ordered porous network and enhanced platelet activation. In a rat liver injury model, the sponge provided stable hemostasis and a rapid resorption profile, confirming its potential as a next-generation rapid-acting hemostatic material.

Limitations

Despite their pronounced hemostatic and regenerative properties, collagen sponges have several important limitations. First, their high porosity—which facilitates rapid hemostasis—also leads to accelerated degradation, reducing mechanical stability within a few days and limiting effectiveness in settings of prolonged bleeding or tissue pressure. Second, collagen is susceptible to active proteolytic degradation, and the resulting fragments may induce local inflammation or alter cellular behavior. Additionally, in anatomical regions exposed to constant mechanical load, collagen sponges can deform easily and lose contact with the wound surface, reducing the stability of the formed clot [37].

7. Gelatin Hemostatic Sponges

Gelatin hemostatic sponges are porous three-dimensional matrices fabricated from denatured animal-derived collagen. Their structure is formed through foaming, freezing, and lyophilizing a gelatin solution, resulting in a soft, elastic matrix that swells extensively upon contact with blood [38]. Owing to their high hydrophilicity, gelatin rapidly absorbs blood, increases in volume, and fills the wound defect, thereby creating mechanical tamponade. The material's porosity and plasticity allow it to conform closely to the irregular surface of parenchymal organs, including deep wound channels [39].

The hemostatic mechanism of gelatin sponges is based primarily on mechanical effects: the sponge swells rapidly, increases localized pressure, and concentrates blood cellular components within its pores. At the same time, gelatin facilitates platelet aggregation and stabilizes the primary clot. When thrombin is added (gelatin-thrombin matrix), hemostasis is achieved much more rapidly—typically within 30-60 seconds—due to direct activation of fibrinogen-to-fibrin conversion [40]. Gelatin sponges also possess the ability to retain bioactive molecules and, in contrast to collagen, demonstrate more predictable degradation with minimal immune response [41].

Several studies emphasize that gelatin sponges, due to their ability to swell 5-10 times their original volume, are particularly effective for diffuse capillary bleeding and in anatomically restricted spaces, such as deep hepatic channels or post-resection cavities [42-44]. Their high plasticity and softness allow application without the risk of tissue trauma when pressure is applied.

In the study by Du et al., published in Biomacromolecules (USA), modified gelatin sponges with dual dynamic crosslinking (GPZ matrix) demonstrated superior hemostatic activity compared with commercial hemostats [23]. The authors reported that the uniform interconnected porous structure ensured rapid blood absorption, increased local concentration of cellular components, and accelerated platelet activation. In rat and rabbit liver-defect models, GPZ reduced hemostasis time by more than 50-60% and exhibited antibacterial and antioxidant properties, decreasing infection risk and accelerating tissue regeneration. These findings confirm that modern gelatin compositions can combine rapid hemostasis with stimulation of parenchymal repair.

In a study by Bhattacharjee et al., published in ACS Biomaterials Science & Engineering, a gelatin hemostatic sponge (Hemobac) reinforced with a cationic chitosan-silver nanocomposite was developed [36]. The material demonstrated rapid hemostasis and potent broad-spectrum antibacterial activity, suppressing bacterial growth by 4-5 log within 6 hours. In mouse models of liver puncture and femoral-vein injury, Hemobac reduced blood loss by 70-80% compared with commercial gelatin sponges, while exhibiting low hemolytic activity and minimal immune response. These results highlight the advantages of composite gelatin systems capable of simultaneously controlling bleeding and preventing wound infection.

In a recent study by Han et al., published in the International Journal of Biological Macromolecules, a gelatin-quaternized chitosan sponge with a macroporous structure formed using natural foaming agents and genipin as a biocrosslinker was proposed [37]. Owing to its large-pore architecture and exceptionally high water-absorbing capacity, the material enabled rapid blood concentration and stable mechanical tamponade, resulting in significantly shorter hemostasis time in a rat liver-injury model, outperforming gauze and standard gelatin sponges. Additionally, GQ2O exhibited pronounced antioxidant and antibacterial properties, reducing inflammation and accelerating healing of a skin defect to near-complete closure by day 14. These results demonstrate that incorporating natural polyphenols and biocompatible crosslinkers can yield safer and more functional gelatin matrices for treating parenchymal bleeding.

An innovative approach was reported by Chu et al., who reinforced a gelatin-chitosan matrix with decellularized liver extracellular-matrix (ECM) powder, creating a biomimetic hemostatic scaffold [38]. This modification improved blood absorption and accelerated clot formation (~50 seconds), significantly outperforming unmodified counterparts. In a rat liver-trauma model, the CG-E4 material facilitated faster wound closure, reduced inflammation, and promoted accelerated biodegradation, indicating better integration with injured parenchyma. These findings confirm that incorporation of organ-specific ECM can substantially enhance the functional performance of gelatin hemostatic sponges in liver surgery.

A different strategy was proposed by Zhang et al., who combined gelatin with silk fibroin and added

thrombin to create a stronger and more physiologically active hemostatic matrix [39]. These composites demonstrated improved mechanical properties, high water-holding capacity, and strong adhesion to blood cellular elements, thereby reducing dynamic coagulation time. In rat models of femoral-artery and liver bleeding, SFG@TB achieved faster hemostasis and lower blood loss compared with pure gelatin and gelatin-fibroin sponges. Moreover, the material enhanced granulation-tissue formation and reduced scar width, highlighting the potential of such composites not only for hemorrhage control but also for improving wound-healing quality.

Limitations

Despite their rapid hemostatic action and high absorbency, modern gelatin sponges retain several important limitations. First, even advanced nanofibrous structures exhibit considerable brittleness and decreased mechanical stability after blood impregnation, which restricts their use in deep or high-tension parenchymal defects [45]. Second, standard gelatin sponges degrade slowly and lack controlled breakdown, which may impede tissue regeneration and prolong inflammatory responses at the implantation site.

Studies also show that in narrow, noncompressible channels, gelatin materials may fail to expand rapidly enough or insufficiently recover their shape, reducing effectiveness in massive parenchymal bleeding [46]. Moreover, high water absorption carries a risk of secondary displacement under blood-flow pressure, particularly in injuries involving major hepatic or splenic vessels. These limitations underscore the need for continued modification of gelatin matrices aimed at improving mechanical strength, achieving faster controlled degradation, and enhancing stability under noncompressible bleeding conditions.

8. Oxidized Regenerated Cellulose

ORC is one of the most extensively studied absorbable topical hemostats and represents a material produced through controlled oxidative modification of cellulose fibers. This processing imparts pronounced acidity and high reactivity to the matrix, ensuring rapid interaction with blood components. The fibrous and porous structure of ORC promotes intensive fluid absorption and converts the material into a uniform gel-like mass that closely conforms to the irregular parenchymal surface [47].

The hemostatic mechanism of ORC is based on a combination of local acidification—which accelerates aggregation of cellular elements—and the formation of a gel-like layer that seals sources of diffuse and capillary bleeding. The negatively charged carboxyl groups further bind plasma proteins, contributing to stabilization of the forming clot. For these reasons, ORC demonstrates high effectiveness in superficial, "oozing" bleeding of the liver and spleen, where rapid coverage of the wound surface and creation of a dense coagulating matrix are required [48,49].

Experimental and clinical evidence shows that the use of oxidized cellulose reduces bleeding time, promotes more uniform clot formation, and reliably seals wound channels and cavities of parenchymal organs. The material adapts well to deep defects, does not require additional fixation, and is suitable in situations where alternative agents act more slowly or less consistently [50-52].

In a study by Kleine et al., several commercial types of ORC differing in oxidation degree, structure, and acidity were compared, demonstrating that these characteristics directly influence tissue interaction [48]. The authors showed that materials with lower pH more rapidly alter the microenvironment of the wound surface and interact more intensely with cells, whereas variants with near-neutral pH exhibited milder effects. Differences in acidity and solubility determined the magnitude of cellular response, depth of tissue impact, and microglial activity in model systems, highlighting the critical role of ORC chemical modification in its biological behavior. These findings indicate that selecting a specific ORC type must account for tissue characteristics and the depth of material-wound interaction.

In a randomized clinical trial, Firmino et al. compared the effectiveness of ORC and calcium alginate in managing bleeding from malignant wounds in patients with breast cancer [49]. Both groups exhibited comparable time to hemostasis; however, ORC required a larger quantity of material to achieve bleeding control, which the authors attributed to differences in wound surfaces and the faster swelling capacity of alginate. No adverse reactions or complications associated with ORC were reported, confirming its clinical safety. These results indicate that the choice between ORC and alginate may depend on wound type and preferred local hemostatic strategy.

In a multicenter retrospective study from South Korea, Rho et al. analyzed 807 surgeries using the ORC SurgiGuard®, evaluating its real-world effectiveness across various surgical disciplines [50]. The use of SurgiGuard® as a monotherapy was associated with higher hemostatic-effect ratings compared with combination therapy involving other agents, both in major and minor procedures. All episodes of rebleeding

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occurred only in cases where multiple hemostats were used together, and no direct association between postoperative complications and ORC was identified. These findings support the clinical utility of ORC as a standalone hemostatic agent with a favorable safety profile.

In orthopedic surgery, the effectiveness of ORC has been confirmed in a recent study by Kaneko et al., evaluating its use during direct anterior approach total hip arthroplasty [51]. The addition of ORC powder to standard topical tranexamic acid therapy significantly reduced total and hidden blood loss (eTBL 679 ± 230 mL vs. 876 ± 293 mL; $p<0.0001$) and decreased postoperative pain severity. Importantly, complication rates did not increase, underscoring the safety of ORC in major reconstructive procedures. The authors highlighted the potential of ORC powder as a valuable adjunct in modern perioperative blood-management protocols.

Limitations

Despite its widespread clinical use, the existing evidence base for ORC remains heterogeneous: included studies vary considerably in surgical profile, bleeding type, endpoints, and comparator agents, which complicates direct comparisons and meta-analytic synthesis [53]. Many studies consist of small randomized trials or retrospective case series, often lacking blinding and subject to risk of bias; therefore, the true advantages of ORC over alternative agents in certain scenarios remain insufficiently defined.

It has been shown that the hemostatic effect of ORC is most pronounced in mild-to-moderate capillary-venous bleeding, whereas in high-pressure arterial bleeding or in vascular/hepatobiliary surgery, it often performs inferiorly to fibrin-containing and other specialized systems that achieve faster hemostasis. Clinical outcomes are also context-dependent: in some models (orthopedics, liver resections), ORC reduces blood loss and drainage volume, whereas in others (certain breast or soft-tissue procedures) its impact on seroma formation, edema, or recovery timelines is minimal.

There is insufficient evidence regarding long-term outcomes (adhesions, chronic infection, late complications), as well as its use in patients with severe coagulopathy, in pediatric populations, or during repeat procedures. These gaps underscore the need for large, methodologically rigorous randomized trials with standardized evaluation criteria to definitively determine the role of ORC in modern surgical hemostasis protocols [54].

9. Fibrin / Thrombin-Fibrin Sponges: Structure, Mechanisms and Effectiveness

Fibrin and thrombin-fibrin hemostatic sponges are biological materials in which active components of the coagulation cascade (fibrinogen, thrombin, factor XIII, aprotinin) are applied in a dry form onto a porous carrier. Collagen, gelatin, or synthetic three-dimensional matrices are typically used as the base, ensuring uniform distribution of the proteins, rapid access of blood to the active components, and firm anchoring of the resulting clot. Upon contact with blood, the sponge rapidly swells, thrombin becomes activated, immediate conversion of fibrinogen into fibrin is initiated, and the fibrous structure of the material entraps platelets, forming a dense and stable coagulation scaffold. This design enables effective function even in the presence of impaired coagulation, anticoagulant therapy, or diffuse bleeding over a large cut surface.

The mechanism of action is based on generating high local concentrations of thrombin and fibrinogen, ensuring almost instantaneous formation of a fibrin layer, mechanical sealing of the organ surface, and stabilization of the developing clot. The carrier provides adhesion to moist parenchymal tissue, uniform distribution of mechanical load, and prevents material displacement. In models of arterial and parenchymal bleeding, fibrin sponges demonstrate faster achievement of hemostasis, reduced time to complete bleeding control, and decreased total blood loss compared with cellulose- or gelatin-based sponges.

Following clinical introduction, the effectiveness of fibrin scaffolds has been repeatedly evaluated in large randomized and multicenter studies. For example, a British group led by Malik and colleagues analyzed outcomes in more than one thousand patients undergoing liver resection of varying extent [53]. Fibrin agents were compared with no local intervention. The authors showed no significant differences in major complications, postoperative mortality, transfusion requirements, or reintervention rates, emphasizing that fibrin sealants should be used only in appropriately justified clinical settings.

In a series of European randomized trials, FBHA were compared with non-biological hemostats—oxidized cellulose, gelatin matrices, and combined polysaccharide materials [55]. Despite the higher biochemical activity of fibrin, investigators found no significant differences in blood loss, transfusion rates, or postoperative complications. The observed trend toward reduced reintervention rates was based on a small number of cases and did not permit definitive conclusions.

Studies involving high-risk patients—those with marked steatofibrosis, cirrhosis, multifocal parenchymal disease, or baseline coagulopathy—are of

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particular interest [56]. Even in this challenging cohort, fibrin sponges did not provide proven reductions in intraoperative or occult blood loss, and the incidence of bile leaks and the mechanical integrity of the coagulation layer remained comparable to alternative hemostatic materials.

International studies conducted during laparoscopic liver resections likewise demonstrated no statistically significant advantages of fibrin agents in reducing drain output, operative time, infectious complications, or recovery duration [57]. Researchers emphasized that the true clinical benefit of fibrin systems is observed only in selected scenarios, whereas in routine practice they do not outperform modern gelatin, cellulose, or composite materials.

Additional research expands understanding of the performance of biological hemostatic systems. Xie and colleagues evaluated a three-dimensional electrospun gelatin matrix containing fibrin components, which enabled rapid clot formation and surpassed traditional sponges in blood absorption and coagulation initiation [40]. Zhang et al. demonstrated that a composition based on silk fibroin, gelatin, and thrombin exhibited improved adhesion, shorter hemostasis times, and accelerated soft-tissue healing compared with gelatin analogues [39]. In a study by Genyk and colleagues comparing fibrin patches with oxidized cellulose during liver resection, fibrin products provided a higher likelihood of achieving hemostasis in the first minutes, although differences in blood loss and complications remained minimal [54]. In vascular-surgery studies by Schenk and colleagues, fibrin materials demonstrated accelerated clot formation, but their effectiveness depended strongly on blood flow and pressure, limiting their utility in high-flow hemorrhage [58].

Limitations

Despite the substantial biological potential of fibrin and thrombin-fibrin hemostats, the evidence supporting their clinical superiority remains limited. First, most randomized studies have small sample sizes, heterogeneous inclusion criteria, and variable assessment methods, reducing the strength of evidence and complicating the development of clear recommendations [59]. Second, in arterial or high-flow parenchymal bleeding, fibrin systems do not outperform synthetic or polysaccharide materials in terms of time to hemostasis or clot stability [60]. Experimental models have demonstrated that the formed fibrin layer may have limited mechanical strength and insufficient resistance to hydrostatic pressure, especially in large-area bleeding surfaces [61]. In addition, biological materials require strict storage conditions, are costly, and may carry risks of immune reactions in sensitized patients due to plasma protein components [62]. These factors underscore the need for selective use of fibrin hemostats in situations where their biological advantages are truly justified.

10. Chitosan Sponges: Structure, Mechanisms, and Effectiveness

Chitosan hemostatic sponges are porous biopolymeric matrices composed of partially deacetylated chitin with a high degree of positive charge due to protonated amino groups. They are typically fabricated via freeze-drying or cryogenic foaming, which creates an open macroporous structure with interconnected channels and a large internal surface capable of rapidly absorbing blood and plasma [63]. The matrix architecture includes large macropores and oriented capillary channels that enable capillary-driven absorption, along with a denser surface layer responsible for mechanical fixation of the forming clot and resistance to displacement during tissue pulsation [64]. To improve strength and achieve controlled degradation, chitosan is often combined with gelatin, collagen, other polysaccharides, or inorganic fillers (e.g., metal-oxide nanoparticles or bioactive glass), enhancing the compressive properties of the sponges and helping them maintain structural integrity under high blood flow [65].

The mechanism of action of chitosan sponges is based on a combination of physicochemical and biological effects. Cationic chitosan electrostatically binds to anionic membranes of erythrocytes and platelets, inducing their rapid aggregation and formation of a dense chitosan-erythrocyte gel on the material surface. The porous structure simultaneously provides intense plasma adsorption, local hemoconcentration, and accumulation of coagulation factors in the contact zone, thereby accelerating activation of the contact (intrinsic) coagulation pathway and stabilizing the fibrin scaffold. In addition, chitosan possesses strong antibacterial activity against both Gram-positive and Gram-negative microorganisms and disrupts bacterial biofilms, reducing the risk of wound infection and making such sponges attractive for contaminated and parenchymal injuries. In experimental models of arterial and parenchymal bleeding, chitosan matrices demonstrate reduced time to hemostasis and formation of a mechanically stable clot even in settings of impaired primary hemostasis, anemia, or hemodilution [66].

The first substantial dataset was provided by Fan et al. from Southwest Jiaotong University, who systematically evaluated the efficacy of chitosan sponges in models of arterial and parenchymal

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bleeding. The authors showed that highly deacetylated chitosan forms a dense cation-induced erythrocyte gel within seconds of contact with blood, reducing time to hemostasis by more than twofold compared with inorganic porous materials. Special attention was paid to the ability of this gel to maintain mechanical stability under hydrostatic pressure, which is critical for injuries to highly perfused organs [65].

A large series of studies from Gheorghita et al. (Carol Davila University of Medicine and Pharmacy) investigated multicomponent chitosan sponges modified with gelatin, collagen, and polysaccharides to enhance absorptive capacity and matrix strength. In preclinical models, such sponges demonstrated strong capillary suction, rapid formation of a dense coagulation scaffold, and high effectiveness even in thrombocytopenia. The authors reported that composite chitosan systems outperformed standard collagen and cellulose materials in terms of hemostasis speed [64].

A notable contribution was made by Lunkov et al. (Bakh Institute of Biochemistry, Moscow), who studied chemically modified forms of chitosan—quaternized, succinylated, and carboxymethylated. These modifications markedly enhanced electrostatic interactions between the biopolymer and erythrocyte membranes, accelerating aggregation of cellular components and stabilizing the developing clot. In several models, the modified forms demonstrated shorter hemostasis times and better adhesion to moist tissues compared with unmodified chitosan and several commercial biopolymer hemostats [66].

In a systematic review from Liu et al. (Jilin University), experimental studies on the use of chitosan sponges in uncontrolled high-flow bleeding were analyzed. The authors noted that the three-dimensional porous architecture, combined with high cationic activity, enables instantaneous formation of a sticky adhesive gel capable of anchoring to intensely bleeding surfaces. In large-vessel injury models, such sponges provided outcomes comparable to advanced commercial hemostats and exceeded those of oxidized cellulose and gelatin matrices [67].

Limitations

Despite the considerable potential of chitosan-based materials, the clinical evidence base remains limited. Most available data originate from preclinical models, while clinical studies involve small patient cohorts and exhibit substantial methodological heterogeneity, making universal recommendations difficult to formulate [68]. The effectiveness of sponges varies markedly depending on the degree of deacetylation, molecular weight, porosity, and type of chemical modification, complicating comparisons across studies [69]. In models of massive pulsatile bleeding, insufficient mechanical stability of the chitosan gel has been observed compared with fibrin-based and composite biopolymeric systems, limiting its applicability in major vascular injuries [70]. An additional limitation is the potential allergenicity of chitin-derived products in individuals sensitized to marine organisms, as well as potential cytotoxicity of heavily modified biopolymer forms [69].

11. Composite Biopolysaccharide Sponges: Structure, Mechanisms, and Effectiveness

Composite biopolysaccharide hemostatic sponges are multicomponent porous matrices in which two or more natural polymers (chitosan, alginate, hyaluronic acid, cellulose, starch, etc.) are integrated into a single structure with predefined mechanical and absorptive properties. The architecture of such materials is designed to combine the strength of one component with the high hydrophilicity or bioactivity of another. The applied modification techniques—varying the degree of chitosan deacetylation, ionic crosslinking (Ca^{2+}, Zn^{2+}), incorporation of additional protein or inorganic elements—enable the production of sponges with high capillary uptake, controlled degradation, and strong adhesion to moist tissues [67].

The mechanisms of hemostatic action are multifactorial. Cationic polymers (chitosan) induce rapid erythrocyte aggregation and formation of a dense erythrocyte-polysaccharide gel, whereas anionic components (alginate, hyaluronate) provide intense plasma absorption and local hemoconcentration, accelerating fibrillogenesis. The porous network promotes rapid blood infiltration through capillary channels, and the presence of carboxyl or phenolic groups enhances adhesion and stabilizes the hemostatic layer. According to experimental models, composite sponges significantly reduce time to hemostasis, decrease total blood loss, and generate a stronger, more displacement-resistant clot compared with monopolymer systems [58].

In vivo studies confirm the effectiveness of such materials, demonstrating rapid formation of a stable coagulation block, reduced risk of secondary bleeding, and favorable biointegration due to gradual matrix biodegradation. An important advantage is strong antibacterial activity, derived from the synergy of cationic polymers and additional functional groups, making composite biopolysaccharide sponges promising for contaminated and infected wounds. Certain modifications also promote accelerated tissue

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repair by stimulating angiogenesis and modulating the local inflammatory response [59,40].

In a study by Du et al., a highly effective composite based on N, O-carboxymethyl chitosan and oxidized cellulose was developed using cryogenic molding followed by lyophilization [70]. The authors showed that the 3D sponge with hierarchical porosity exhibited exceptionally high-water absorption capacity, compressive strength, and pronounced cationic surface charge. In vitro testing demonstrated rapid erythrocyte and platelet binding, marked reduction in clotting time, and broad-spectrum antibacterial activity. In models of massive liver bleeding and arterial injury, the composite sponge achieved faster hemostasis and reduced blood loss compared with monocomponent chitosan and cellulose analogues [41].

Another research group developed a nanocellulose-reinforced alginate/chitosan sponge in which anionic alginate provided intensive capillary plasma absorption, cationic chitosan facilitated aggregation of blood cells, and nanocrystalline cellulose functioned as a reinforcing scaffold. This design enabled controlled porosity, high elasticity, and stable structure under repeated compression. In rat models of skin and parenchymal bleeding, this sponge significantly shortened time to hemostasis and reduced total blood loss compared with gauze and a commercial gelatin sponge, while also accelerating epithelization and formation of mature granulation tissue [42].

A number of studies have examined starch-chitosan composite sponges designed for severe, uncontrolled hemorrhage. By combining low-cost, highly absorbent modified starch with cationic chitosan, researchers obtained materials with high swelling capacity, rapid formation of a dense erythrocyte-polysaccharide gel, and sufficient mechanical strength for tamponade of deep wounds. In models of massive liver and major-vessel bleeding, these composites reduced blood loss by more than 50% and significantly decreased time to stable hemostasis compared with traditional gauze and several monosaccharide sponges [13].

Limitations

Despite promising results, the evidence base for composite biopolysaccharide sponges remains predominantly preclinical and highly heterogeneous. Polymer composition, degree of modification, types of ionic crosslinking, pore size, and testing methodologies differ substantially across studies, complicating direct comparison of effectiveness and limiting translation into clinical practice. Many fabrication protocols involve complex synthesis schemes with potentially toxic crosslinkers or organic solvents, requiring additional validation of biosafety and verification of reagent removal [44]. Issues also arise regarding standardization of degradation rate: excessively slow resorption may lead to chronic inflammation and foreign-body reactions, whereas overly rapid matrix breakdown reduces duration of the hemostatic effect [35]. Finally, there are virtually no large randomized clinical trials comparing composite biopolysaccharide sponges with established cellulose, gelatin, or fibrin systems, which currently prevents recommending these materials as standard treatment options for parenchymal or arterial bleeding [26].

12. Discussion

Modern hemostatic sponges based on natural and composite biopolymers demonstrate substantial progress compared with traditional gauze and cellulose-based materials. The development of new matrices, their chemical modification, and the incorporation of functional components make it possible to obtain dressings with directed porous architecture, high absorptive capacity, strong adhesion, and rapid formation of a durable coagulation layer. Analysis of published experimental and clinical studies confirms that the effectiveness of biopolysaccharide sponges is determined not only by the nature of the base polymer, but also by the combination of structural elements, degree of crosslinking, surface charge, and the presence of bioactive additives.

Fibrin-based materials remain one of the most physiologically relevant approaches to local hemostasis due to their direct participation in the coagulation cascade and their ability to form a robust fibrin scaffold; however, their advantages are realized primarily in controlled capillary bleeding and in specific types of parenchymal injury. Chitosan sponges exhibit rapid onset of hemostasis through cation-induced aggregation of cellular elements and formation of a stable erythrocyte–polysaccharide gel, as well as pronounced antibacterial activity, making them particularly promising for wounds with a high risk of infection. Composite biopolysaccharide systems, which merge the strengths of several polymers (chitosan, alginate, hyaluronate, starch, cellulose), provide the best balance among hemostasis speed, mechanical stability, biocompatibility, and antimicrobial properties.

For systematic comparison of different types of hemostatic materials, we additionally performed an integral comparative assessment of the key properties of four major classes of sponges, including hemostasis speed, clot stability, antimicrobial activity, blood-loss

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reduction, biocompatibility, and degree of clinical evidence. To enhance clarity, the resulting data were summarized in the form of a heat map (Figure 3), which enabled a visual representation of the advantages and limitations of each material class on a unified scale.

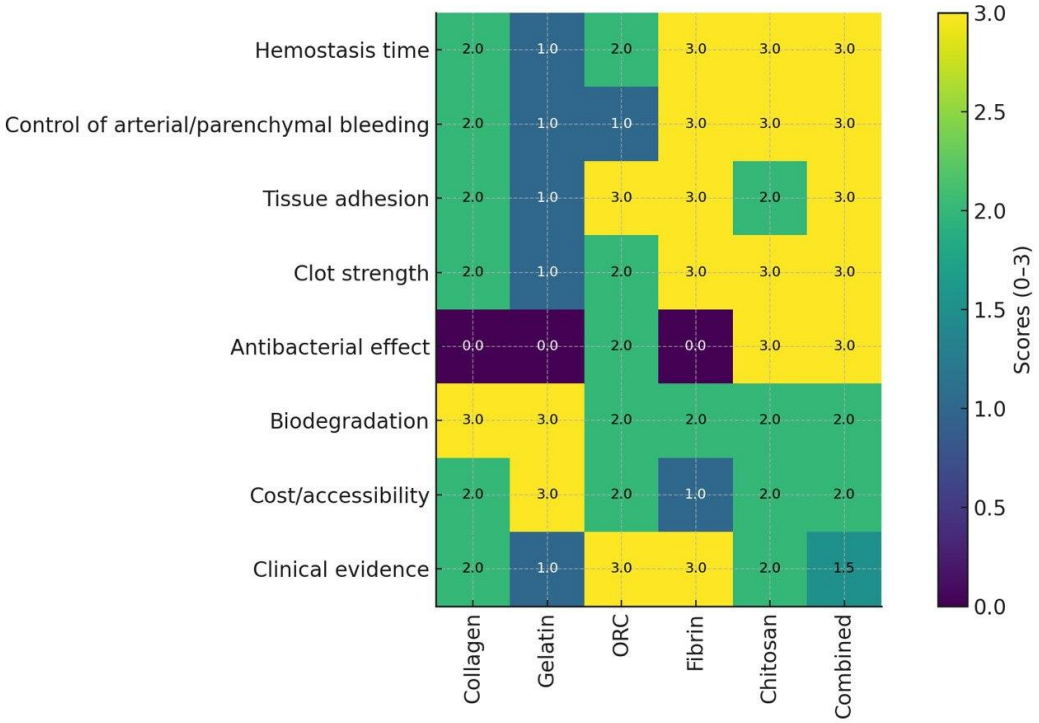

Figure 3 – Heat map of the comparative effectiveness of four types of hemostatic sponges across six key characteristics: hemostasis speed (A), clot stability (B), impact on blood-loss volume (C), antimicrobial activity (D), biocompatibility/degradation (E), clinical evidence base (F). Darker shades correspond to lower parameter values

As shown in the visualization, the most balanced combination of key characteristics is observed in composite biopolysaccharide systems, which integrate high sorption capacity, cation-induced aggregation of cellular elements, and pronounced antibacterial properties. Fibrin and chitosan sponges provide the most rapid hemostasis, yet are inferior in terms of breadth of clinical evidence and universality of use. Oxidized cellulose remains optimal for superficial and diffuse capillary bleeding but demonstrates lower mechanical stability of the clot. Such an integrated assessment simplifies material selection in clinical practice and highlights the need for further development of composite biopolysaccharide systems as the most promising universal hemostatic agents.

Despite the clear progress, selection of the optimal hemostatic material must account for the clinical situation, the nature of the bleeding, the presence of concomitant coagulopathies, as well as availability and cost of the specific product. Several studies note that the advantages of fibrin sponges diminish in high-flow or pulsatile bleeding, whereas chitosan and composite matrices demonstrate more stable performance. Modern biopolymer sponges are increasingly used not only in inpatient surgery but also in outpatient, field, and domestic settings due to their ease of application, rapid action, and ability to reduce the need for specialized dressings. Their expanding sphere of use includes dentistry, cosmetology, trauma care, military medicine, and emergency bleeding control. Further development of this field will likely involve integration of composite matrices, locally released antimicrobial substances, growth factors, and intelligent systems for controlled degradation.

At the same time, the available evidence must be interpreted with caution: included studies differ markedly in design, bleeding models, and material characteristics, which limits direct comparability of results. Some data are derived from preclinical experiments that do not fully replicate real clinical conditions. Many composite biopolysaccharide materials are still in early stages of development, and existing publications often represent preliminary or pilot studies. Nevertheless, current evidence consistently demonstrates the effectiveness of these systems and supports their further refinement and clinical translation.

13. Conclusions

Hemostatic sponges based on natural and composite biopolysaccharides represent a promising direction in the local control of bleeding, demonstrating higher effectiveness, ease of use, and biocompatibility compared with traditional dressing materials. The use of chitosan, fibrin, alginate, and their modifications enables the creation of dressings with rapid onset of hemostasis, strong adhesion, antibacterial properties, and the ability to support physiological tissue healing.

Composite structures provide the most optimal balance of mechanical strength, speed of action, and biological activity, making them particularly promising for the treatment of difficult-to-control, infected, and parenchymal hemorrhage. The emergence of materials containing growth factors, silver, antibiotics, and composite systems with controlled release confirms the rapid development of this field over the past five years.

Despite the obtained results, the final choice of a hemostatic dressing should be based on the pathogenic mechanisms of injury, the volume of blood loss, the risk of infection, and the availability of materials. The optimal option is biopolymer matrices that combine hemostatic, antibacterial, and regenerative properties.

Conflicts of Interest. The authors declare no conflicts of interest.

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References

1. Boonstra, E. A., Molenaar, I. Q., Porte, R. J., & de Boer, M. T. (2009). Topical haemostatic agents in liver surgery: do we need them?. HPB : the official journal of the International Hepato Pancreato Biliary Association, 11(4), 306–310. https://doi.org/10.1111/j.1477-2574.2009.00065.x

2. Brustia, R., Granger, B., & Scatton, O. (2016). An update on topical haemostatic agents in liver surgery: systematic review and meta-analysis. Journal of hepato-biliary-pancreatic sciences, 23(10), 609–621. https://doi.org/10.1002/jhbp.389

3. Robledo, A. B., Seller, A. N., & Tamarit, M. N. (2021). Is the Use of Sealing and Hemostatic Agents Justified in Hepatic Resections. Review and Meta-analysis. J Healthcare, 4(1), 39-45. https://doi.org/10.36959/879/380

4. Fischer, L., Seiler, C. M., Broelsch, C. E., de Hemptinne, B., Klempnauer, J., Mischinger, H. J., Gassel, H. J., Rokkjaer, M., Schauer, R., Larsen, P. N., Tetens, V., & Büchler, M. W. (2011). Hemostatic efficacy of TachoSil in liver resection compared with argon beam coagulator treatment: an open, randomized, prospective, multicenter, parallel-group trial. Surgery, 149(1), 48–55. https://doi.org/10.1016/j.surg.2010.02.008

5. Kakaei, F., Seyyed Sadeghi, M. S., Sanei, B., Hashemzadeh, S., & Habibzadeh, A. (2013). A randomized clinical trial comparing the effect of different haemostatic agents for haemostasis of the liver after hepatic resection. HPB surgery: a world journal of hepatic, pancreatic and biliary surgery, 2013, 587608. https://doi.org/10.1155/2013/587608

6. Huang, L., Liu, G. L., Kaye, A. D., & Liu, H. (2020). Advances in Topical Hemostatic Agent Therapies: A Comprehensive Update. Advances in therapy, 37(10), 4132–4148. https://doi.org/10.1007/s12325-020-01467-y

7. Deineka, V., Sulaieva, O., Pernakov, N., Radwan-Pragłowska, J., Janus, L., Korniienko, V., Husak, Y., Yanovska, A., Liubchak, I., Yusupova, A., Piątkowski, M., Zlatska, A., & Pogorielov, M. (2021). Hemostatic performance and biocompatibility of chitosan-based agents in experimental parenchymal bleeding. Materials science & engineering. C, Materials for biological applications, 120, 111740. https://doi.org/10.1016/j.msec.2020.111740

8. Du, X., Wu, L., Yan, H., Jiang, Z., Li, S., Li, W., Bai, Y., Wang, H., Cheng, Z., Kong, D., Wang, L., & Zhu, M. (2021). Microchannelled alkylated chitosan sponge to treat noncompressible hemorrhages and facilitate wound healing. Nature communications, 12(1), 4733. https://doi.org/10.1038/s41467-021-24972-2

9. Yudin, A. B., Nosov, A. M., Volkova, M. V., Demchenko, K. N., Zhabin, A. V., Zaychikov, D. A., ... & Kovalevsky, Y. B. (2025). Evaluation of the Safety and Efficacy of Chitosan-Based Hemostatic Sponges in a Chronic Large-Animal Model. Russian Military Medical Academy Reports, 44(1), 19-26. https://doi.org/10.17816/rmmar641798

10. Fu, H., Amantay, M., Kim, J., Jiang, T., Pan, H., & Wang, Y. (2025). Constructing a hemostatic sponge loaded with copper nanoparticles and carboxymethyl chitosan for wound hemostasis and infection prevention. Biomaterials science, 13(15), 4245–4263. https://doi.org/10.1039/d5bm00556f

11. Sánchez-Del-Valle, F. J., Sánchez-Seco, M. I., Jiménez, A. G., Acosta, F., Fernández-Domínguez, P., & Pérez-Alegre, J. J. (2024). Effectiveness of a thrombin-gelatin flowable for treating severe liver bleeding: an experimental study. BMC gastroenterology, 24(1), 71. https://doi.org/10.1186/s12876-023-03114-6

12. Sánchez Del Valle, F. J., De Nicolás, L., Fernández, G., Fernández, P., Gómez, E., & Aranaz Corral, I. (2023). Comparison of a gelatin thrombin versus a modified absorbable polymer as a unique treatment for severe hepatic hemorrhage in swine. Scientific reports, 13(1), 20854. https://doi.org/10.1038/s41598-023-41983-9

13. Lim, S. Y., Choi, G. H., Lim, J. H., Han, H. S., Yoon, Y. S., Lee, H. W., Lee, B., Park, Y., Kang, M., Kim, J., Joo, H., & Cho, J. Y. (2025). A Prospective, Multicenter, Randomized, Noninferiority Trial of Stopad® Versus Tachosil® for Hemostasis After Liver Resection. Cancers, 17(5), 757. https://doi.org/10.3390/cancers17050757

14. de Wilt, J. H. W., Verhoef, C., de Boer, M. T., Stommel, M. W. J., van der Plas-Kemper, L., Garms, L. M., van der Zijden, C. J., Head, S. J., Bender, J. C. M. E., van Goor, H., & Porte, R. J. (2024). Clinical Safety and Performance of GATT-Patch for Hemostasis in Minimal to Moderate Bleeding During Open Liver Surgery. The Journal of surgical research, 298, 316–324. https://doi.org/10.1016/j.jss.2024.03.033

15. Jamali, B., Nouri, S., & Amidi, S. (2024). Local and Systemic Hemostatic Agents: A Comprehensive Review. Cureus, 16(10), e72312. https://doi.org/10.7759/cureus.72312

16. López-Guerra, D., Santos-Naharro, J., Rojas-Holguín, A., Jaen-Torrejimeno, I., Prada-Villaverde, A., & Blanco-Fernández, G. (2019). Postoperative bleeding and biliary leak after liver resection: A cohort study between two different fibrin sealant patches. Scientific reports, 9(1), 12001. https://doi.org/10.1038/s41598-019-48529-y

17. Rostami, F., Tamjid, E., & Behmanesh, M. (2020). Drug-eluting PCL/graphene oxide nanocomposite scaffolds for enhanced osteogenic differentiation of mesenchymal stem cells. Materials science & engineering. C, Materials for biological applications, 115, 111102. https://doi.org/10.1016/j.msec.2020.111102

18. Zou, C. Y., Han, C., Xing, F., Jiang, Y. L., Xiong, M., Li-Ling, J., & Xie, H. Q. (2024). Smart design in biopolymer-based hemostatic sponges: From hemostasis to multiple functions. Bioactive materials, 45, 459–478. https://doi.org/10.1016/j.bioactmat.2024.11.034

19. Yu, P., & Zhong, W. (2021). Hemostatic materials in wound care. Burns & trauma, 9, tkab019. https://doi.org/10.1093/burnst/tkab019

20. Behrens, A. M., Sikorski, M. J., & Kofinas, P. (2014). Hemostatic strategies for traumatic and surgical bleeding. Journal of biomedical materials research. Part A, 102(11), 4182–4194. https://doi.org/10.1002/jbm.a.35052

21. Malik, A., Rehman, F. U., Shah, K. U., Naz, S. S., & Qaisar, S. (2021). Hemostatic strategies for uncontrolled bleeding: A comprehensive update. Journal of biomedical materials research. Part B, Applied biomaterials, 109(10), 1465–1477. https://doi.org/10.1002/jbm.b.34806

22. Zhou, W., Yang, T., Xu, W., Huang, Y., Ran, L., Yan, Y., ... & Cao, Y. (2022). The polysaccharides from the fruits of Lycium barbarum L. confer anti-diabetic effect by regulating gut microbiota and intestinal barrier. Carbohydrate Polymers, 291, 119626. https://doi.org/10.1016/j.carbpol.2022.119626

23. Du, J., Wang, J., Xu, T., Yao, H., Yu, L., & Huang, D. (2023). Hemostasis Strategies and Recent Advances in Nanomaterials for Hemostasis. Molecules (Basel, Switzerland), 28(13), 5264. https://doi.org/10.3390/molecules28135264

24. Xu, H., Liu, Y., Qiu, L., Mangue, A. L. M. M., Zhang, J., Wei, B., ... & Wang, H. (2025). Preparation and application of collagen-based hemostatic materials: a review. Collagen and Leather, 7(1), 11. https://doi.org/10.1186/s42825-025-00193-x

25. Manon-Jensen, T., Kjeld, N. G., & Karsdal, M. A. (2016). Collagen-mediated hemostasis. Journal of thrombosis and haemostasis: JTH, 14(3), 438–448. https://doi.org/10.1111/jth.13249

26. He, Y., Wang, J., Si, Y., Wang, X., Deng, H., Sheng, Z., Li, Y., Liu, J., & Zhao, J. (2021). A novel gene recombinant collagen hemostatic sponge with excellent biocompatibility and hemostatic effect. International journal of biological macromolecules, 178, 296–305. https://doi.org/10.1016/j.ijbiomac.2021.02.162

27. Wang, L., Li, W., Qu, Y., Wang, K., Lv, K., He, X., & Qin, S. (2022). Preparation of Super Absorbent and Highly Active Fish Collagen Sponge and its Hemostatic Effect in vivo and in vitro. Frontiers in bioengineering and biotechnology, 10, 862532. https://doi.org/10.3389/fbioe.2022.862532

28. Chang C. T. (2023). The hemostatic effect and wound healing of novel collagen-containing polyester dressing. Journal of biomaterials science. Polymer edition, 34(15), 2124–2143. https://doi.org/10.1080/09205063.2023.2230842

29. Yang, Y., Zhang, Y., Min, Y., & Chen, J. (2022). Preparation of methacrylated hyaluronate/methacrylated collagen sponges with rapid shape recovery and orderly channel for fast blood absorption as hemostatic dressing. International journal of biological macromolecules, 222(Pt A), 30-40. https://doi.org/10.1016/j.ijbiomac.2022.09.054

30. D'Amico, E., Pierfelice, T. V., Lepore, S., Iezzi, G., D'Arcangelo, C., Piattelli, A., Covani, U., & Petrini, M. (2023). Hemostatic Collagen Sponge with High Porosity Promotes the Proliferation and Adhesion of Fibroblasts and Osteoblasts. International journal of molecular sciences, 24(9), 7749. https://doi.org/10.3390/ijms24097749

31. Weber, L. M., Lopez, C. G., & Anseth, K. S. (2009). Effects of PEG hydrogel crosslinking density on protein diffusion and encapsulated islet survival and function. Journal of Biomedical Materials Research Part A: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials, 90(3), 720-729. https://doi.org/10.1002/jbm.a.32134

32. Anderson, T. S., Hattersley, R. D., & Demetriou, J. L. (2025). A randomized comparison of an adhesive gelatin sponge and a plain collagen sponge for hemostatic control during canine liver surgery. Veterinary surgery: VS, 54(2), 345–353. https://doi.org/10.1111/vsu.14160

33. Albala D. M. (2003). Fibrin sealants in clinical practice. Cardiovascular surgery (London, England), 11 Suppl 1, 5–11. https://doi.org/10.1016/S0967-2109(03)00065-6

34. Washio, A., Kérourédan, O., Kitamura, C., & Tabata, Y. (2025). Biocompatibility and bioactivity of gelatin hydrogel sponges incorporating bioactive glasses capable of controlled release of basic fibroblast growth factor. Journal of biomaterials science. Polymer edition, 1–22. Advance online publication. https://doi.org/10.1080/09205063.2025.2544947

35. Lan, G., Lu, B., Wang, T., Wang, L., Chen, J., Yu, K., Liu, J., Dai, F., & Wu, D. (2015). Chitosan/gelatin composite sponge is an absorbable surgical hemostatic agent. Colloids and surfaces. B, Biointerfaces, 136, 1026–1034. https://doi.org/10.1016/j.colsurfb.2015.10.039

36. Bhattacharjee, B., Mukherjee, R., & Haldar, J. (2022). Biocompatible Hemostatic Sponge Exhibiting Broad-Spectrum Antibacterial Activity. ACS biomaterials science & engineering, 8(8), 3596–3607. https://doi.org/10.1021/acsbiomaterials.2c00410

37. Han, Q., Zhao, F., Wu, T., Zhao, C., Li, J., Huang, S., Zhang, T., & Xing, J. (2025). Gelatin/quaternized chitosan-based macroporous sponge inspired by food foaming for rapid hemostasis and wound healing. International journal of biological macromolecules, 320(Pt 4), 146117. https://doi.org/10.1016/j.ijbiomac.2025.146117

38. Chu, T. L., Tripathi, G., Bae, S. H., & Lee, B. T. (2021). In-vitro and in-vivo hemostat evaluation of decellularized liver extra cellular matrix loaded chitosan/gelatin spongy scaffolds for liver injury. International journal of biological macromolecules, 193(Pt A), 638-646. https://doi.org/10.1016/j.ijbiomac.2021.10.128

39. Zhang, Y., Li, M., Chang, J., Li, C., Hui, Y., Wang, Y., & Xu, W. (2024). Silk fibroin-gelatine haemostatic sponge loaded with thrombin for wound haemostasis and tissue regeneration. Burns & trauma, 12, tkae026. https://doi.org/10.1093/burnst/tkae026

40. Xie, X., Li, D., Chen, Y., Shen, Y., Yu, F., Wang, W., Yuan, Z., Morsi, Y., Wu, J., & Mo, X. (2021). Conjugate Electrospun 3D Gelatin Nanofiber Sponge for Rapid Hemostasis. Advanced healthcare materials, 10(20), e2100918. https://doi.org/10.1002/adhm.202100918

41. Zhu, Y., Zhang, L., Duan, W., Martin-Saldaña, S., Li, C., Yu, H., Feng, L., Zhang, X., Du, B., Li, G., Zheng, X., & Bu, Y. (2023). Succinic Ester-Based Shape Memory Gelatin Sponge for Noncompressible Hemorrhage without Hindering Tissue Regeneration. Advanced healthcare materials, 12(5), e2202122. https://doi.org/10.1002/adhm.202202122

42. Tomizawa, Y. (2005). Clinical benefits and risk analysis of topical hemostats: a review. Journal of artificial organs: the official journal of the Japanese Society for Artificial Organs, 8(3), 137–142. https://doi.org/10.1007/s10047-005-0296-x

43. Yang, Y., Lu, Y. T., Zeng, K., Heinze, T., Groth, T., & Zhang, K. (2021). Recent Progress on Cellulose-Based Ionic Compounds for Biomaterials. Advanced materials (Deerfield Beach, Fla.), 33(28), e2000717. https://doi.org/10.1002/adma.202000717

44. Spotnitz, W. D., & Burks, S. (2010). State-of-the-art review: Hemostats, sealants, and adhesives II: Update as well as how and when to use the components of the surgical toolbox. Clinical and applied thrombosis/hemostasis: official journal of the International Academy of Clinical and Applied Thrombosis/Hemostasis, 16(5), 497–514. https://doi.org/10.1177/1076029610363589

45. Ye, L., Xiao, X., & Zhu, L. (2017). The Comparison of Etomidate and Propofol Anesthesia in Patients Undergoing Gastrointestinal Endoscopy: A Systematic Review and Meta-Analysis. Surgical laparoscopy, endoscopy & percutaneous techniques, 27(1), 1–7. https://doi.org/10.1097/SLE.0000000000000373

46. Chang, Y. F., Chao, A., Shih, P. Y., Hsu, Y. C., Lee, C. T., Tien, Y. W., Yeh, Y. C., Chen, L. W., & NTUH Center of Microcirculation Medical Research (NCMMR) (2018). Comparison of dexmedetomidine versus propofol on hemodynamics in surgical critically ill patients. The Journal of surgical research, 228, 194–200. https://doi.org/10.1016/j.jss.2018.03.040

47. Cheng, W., He, J., Wu, Y., Song, C., Xie, S., Huang, Y., & Fu, B. (2013). Preparation and characterization of oxidized regenerated cellulose film for hemostasis and the effect of blood on its surface. Cellulose, 20(5), 2547-2558. https://doi.org/10.1007/s10570-013-0005-5

48. Kleine, J., Leisz, S., Ghadban, C., Hohmann, T., Prell, J., Scheller, C., Strauss, C., Simmermacher, S., & Dehghani, F. (2021). Variants of Oxidized Regenerated Cellulose and Their Distinct Effects on Neuronal Tissue. International journal of molecular sciences, 22(21), 11467. https://doi.org/10.3390/ijms222111467

49. Firmino, F., Villela-Castro, D., & Santos, V. L. C. G. (2024). Oxidized Regenerated Cellulose Versus Calcium Alginate in Controlling Bleeding From Malignant Wounds: A Randomized Controlled Trial. Cancer nursing, 47(5), 377-387. https://doi.org/10.1097/NCC.0000000000001235

50. Rho, S. Y., Jin, M., Kim, H. K., Park, J. I., Park, J. H., Yun, S., Lee, M., Choi, S. B., Hong, J. Y., & Kim, K. S. (2023). The novel use and feasibility of hemostatic oxidized regenerated cellulose agent (SurgiGuard®): multicenter retrospective study. Gland surgery, 12(7), 905-916. https://doi.org/10.21037/gs-22-675

51. Kaneko T., Hayakawa K., Miyazaki T. Clinical efficacy of oxidized regenerated cellulose powder in perioperative blood management in direct anterior total hip arthroplasty. SICOT J. 2025;11:36. PMCID: PMC12266662. PMID: 40668976. https://doi.org/10.1051/sicotj/2025036

52. Kanagal, D., Rao, K., Gathoga, P., Moharana, K., Patil, R., Jaiswal, P., Ap, V., & Ts, D. (2025). Biomaterial-Based Hemostasis: A Review of the Clinical and Functional Versatility of Oxidized Regenerated Cellulose. Cureus, 17(10), e94602. https://doi.org/10.7759/cureus.94602

53. Malik, A. K., Amer, A. O., Tingle, S. J., Thompson, E. R., White, S. A., Manas, D. M., & Wilson, C. (2023). Fibrin-based haemostatic agents for reducing blood loss in adult liver resection. The Cochrane database of systematic reviews, 8(8), CD010872. https://doi.org/10.1002/14651858.CD010872.pub2

54. Genyk, Y., Kato, T., Pomposelli, J. J., Wright, J. K., Jr, Sher, L. S., Tetens, V., & Chapman, W. C. (2016). Fibrin Sealant Patch (TachoSil) vs Oxidized Regenerated Cellulose Patch (Surgicel Original) for the Secondary Treatment of Local Bleeding in Patients Undergoing Hepatic Resection: A Randomized Controlled Trial. Journal of the American College of Surgeons, 222(3), 261–268. https://doi.org/10.1016/j.jamcollsurg.2015.12.007

55. Lavigne, J. P., Postal, A., Kolh, P., & Limet, R. (2003). Prosthetic vascular infection complicated or not by aortoenteric fistula: comparison of treatment with and without cryopreserved allograft (homograft). European journal of vascular and endovascular surgery, 25(5), 416-423. https://doi.org/10.1053/ejvs.2002.1865

56. Chetter, I., Stansby, G., Sarralde, J. A., Riambau, V., Giménez-Gaibar, A., MacKenzie, K., Acín, F., Navarro-Puerto, J., & Investigators of the Fibrin Sealant Grifols Study Group (2017). A Prospective, Randomized, Multicenter Clinical Trial on the Safety and Efficacy of a Ready-to-Use Fibrin Sealant as an Adjunct to Hemostasis during Vascular Surgery. Annals of vascular surgery, 45, 127–137. https://doi.org/10.1016/j.avsg.2017.06.043

57. Karna, R., Deliwala, S., Ramgopal, B., Mohan, B. P., Kassab, L., Becq, A., Dhawan, M., & Adler, D. G. (2023). Efficacy of topical hemostatic agents in malignancy-related GI bleeding: a systematic review and meta-analysis. Gastrointestinal endoscopy, 97(2), 202–208.e8. https://doi.org/10.1016/j.gie.2022.07.033

58. Spotnitz W. D. (2014). Fibrin Sealant: The Only Approved Hemostat, Sealant, and Adhesive-a Laboratory and Clinical Perspective. ISRN surgery, 2014, 203943. https://doi.org/10.1155/2014/203943

59. Jackson M. R. (2001). Fibrin sealants in surgical practice: An overview. American journal of surgery, 182(2 Suppl), 1S–7S. https://doi.org/10.1016/s0002-9610(01)00770-x

60. Sierra D. H. (1993). Fibrin sealant adhesive systems: a review of their chemistry, material properties and clinical applications. Journal of biomaterials applications, 7(4), 309–352. https://doi.org/10.1177/088532829300700402

61. Klokkevold, P. R., Fukayama, H., Sung, E. C., & Bertolami, C. N. (1999). The effect of chitosan (poly-N-acetyl glucosamine) on lingual hemostasis in heparinized rabbits. Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons, 57(1), 49–52. https://doi.org/10.1016/s0278-2391(99)90632-8

62. Zhang, J., Xia, W., Liu, P., Cheng, Q., Tahirou, T., Gu, W., & Li, B. (2010). Chitosan modification and pharmaceutical/biomedical applications. Marine drugs, 8(7), 1962–1987. https://doi.org/10.3390/md8071962

63. Kheirabadi, B. S., Mace, J. E., Terrazas, I. B., Fedyk, C. G., Estep, J. S., Dubick, M. A., & Blackbourne, L. H. (2010). Safety evaluation of new hemostatic agents, smectite granules, and kaolin-coated gauze in a vascular injury wound model in swine. The Journal of trauma, 68(2), 269–278. https://doi.org/10.1097/TA.0b013e3181c97ef1

64. Gheorghiță, D., Moldovan, H., Robu, A., Bița, A. I., Grosu, E., Antoniac, A., Corneschi, I., Antoniac, I., Bodog, A. D., & Băcilă, C. I. (2023). Chitosan-Based Biomaterials for Hemostatic Applications: A Review of Recent Advances. International journal of molecular sciences, 24(13), 10540. https://doi.org/10.3390/ijms241310540

65. Fan, P., Zeng, Y., Zaldivar-Silva, D., Agüero, L., & Wang, S. (2023). Chitosan-Based Hemostatic Hydrogels: The Concept, Mechanism, Application, and Prospects. Molecules (Basel, Switzerland), 28(3), 1473. https://doi.org/10.3390/molecules28031473

66. Lunkov, A. P., Zubareva, A. A., Varlamov, V. P., Nechaeva, A. M., & Drozd, N. N. (2023). Chemical modification of chitosan for developing of new hemostatic materials: A review. International journal of biological macromolecules, 253(Pt 8), 127608. https://doi.org/10.1016/j.ijbiomac.2023.127608

67. Liu, Z., Xu, Y., Su, H., Jing, X., Wang, D., Li, S., Chen, Y., Guan, H., & Meng, L. (2023). Chitosan-based hemostatic sponges as new generation hemostatic materials for uncontrolled bleeding emergency: Modification, composition, and applications. Carbohydrate polymers, 311, 120780. https://doi.org/10.1016/j.carbpol.2023.120780

68. Cheng, F., Xu, L., Dai, J., Yi, X., He, J., & Li, H. (2022). N, O-carboxymethyl chitosan/oxidized cellulose composite sponge containing ε-poly-l-lysine as a potential wound dressing for the prevention and treatment of postoperative adhesion. International journal of biological macromolecules, 209(Pt B), 2151–2164. https://doi.org/10.1016/j.ijbiomac.2022.04.195

69. Asadzadeh, F., Ghorbanzadeh, S., Poursattar Marjani, A., Gholami, R., Asadzadeh, F., & Lotfollahi, L. (2024). Assessing polylactic acid nanofibers with cellulose and chitosan nanocapsules loaded with chamomile extract for treating gram-negative infections. Scientific reports, 14(1), 22336. https://doi.org/10.1038/s41598-024-72398-9

70. Du, F., A, W., Liu, F., Wu, B., Liu, Y., Zheng, W., Feng, W., Li, G., & Wang, X. (2023). Hydrophilic chitosan/graphene oxide composite sponge for rapid hemostasis and non-rebleeding removal. Carbohydrate polymers, 316, 121058. https://doi.org/10.1016/j.carbpol.2023.121058

Паренхиматоздық қан кетуді емдеуге арналған заманауи гемостатикалық губкалар: Құрамы, әсер ету механизмдері және клиникалық тиімділігі. Әдебиетке шолу

Алжанов Е. [1], Рамазанов Ж. [2], Ахметкаримова Ж. [3], Балгазаров С. [4], Римашеский Д. [5], Атепилева А.[6], Sari Al Hajaj [7], Унышева Г. [8], Криворучко Т. [9], Жуликеева А. [10]

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Түйіндеме

Бауыр, көкбауыр және бүйрек жарақаттарынан туындайтын паренхималық қан кету диффузиялық сипатына, айқын қан кету нүктесінің болмауына және коагулопатия қаупінің жоғары болуына байланысты емдеуге ең қиын қан кету түрлерінің бірі болып табылады. Механикалық гемостаз, электрокоагуляция және тампонада кеңінен қолданылғанына қарамастан, олардың тиімділігі терең немесе көп ошақты паренхималық жарақаттар жағдайында шектеулі болып қала береді. Сондықтан, жедел және жоспарлы хирургиялық араласуда әртүрлі гемостатикалық губкаларды қолдану маңызды болып келеді. Әртүрлі санаттағы жергілікті гемостатикалық материалдарға арналған преклиникалық және клиникалық зерттеулерді талдау арқылы

паренхиматоздық қан кетуді емдеуде гемостатикалық губкалардың тиімділігін бағалау. Паренхиматоздық қан кетуді емдеуге арналған жануарлық, өсімдік және синтетикалық тектегі гемостатикалық губкалардың тиімділігін бағалаған доклиникалық және клиникалық зерттеулерге, жүйелі шолулар мен метаанализдерге жан-жақты талдау жүргізілді. Іздеу 2019–2025 жылдар аралығында PubMed, MedLine және Scopus дерекқорларында жүргізілді. Пайдаланылған негізгі сөздер: гемостатикалық губка, паренхиматоздық қан кету, жергілікті гемостаз, коллагенді губка, желатинді губка, хитозанды губка. Барлығы 213 жарияланым анықталды; олардың 119-ы алдын ала белгіленген критерийлерге сәйкес (қайталану, дәлел деңгейінің жеткіліксіздігі, паренхиматоздық ағзалар бойынша деректердің болмауы) алып тасталды. Қорытынды талдауға қосу критерийлеріне сәйкес келетін 94 зерттеу енгізілді. Зерттеулердің басым бөлігі гемостатикалық губкаларды қолдану қан кетуді тоқтату үшін қажет уақытты едәуір қысқартатынын, операция кезіндегі қан жоғалтуды азайтатынын және стандартты гемостатикалық әдістермен салыстырғанда қайталама қан кету қаупін төмендететінін көрсетеді. Ең кең зерттелген материалдарға коллаген, желатин, оксидтелген целлюлоза, фибрин және хитозан негізіндегі губкалар жатады, олардың әрқайсысы өзіндік әсер ету механизмімен ерекшеленеді. Салыстырмалы талдау көптеген губкалардың клиникалық тиімділігі ұқсас екенін, алайда оңтайлы таңдау жараның сипаттамалары мен интраоперациялық жағдайларға байланысты болатынын анықтайды. Қазіргі уақытта паренхиматоздық қан кетуді емдеуге арналған гемостатикалық губкалардың кең таңдауы бар, дегенмен әмбебап әрі мінсіз материал әзірге жоқ. Бұл шолу жергілікті гемостатикалық губкалардың гемостазға қол жеткізудің стандартты әдістеріне негізделген және клиникалық тұрғыдан тиімді екенін растайды.

Түйін сөздер: гемостатикалық губкалар, жергілікті гемостаз, паренхиматоздық қан кету, коллаген, желатин, хитозан.

Современные гемостатические губки для паренхиматозного кровотечения: состав, механизмы действия и клиническая эффективность. Обзор литературы

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Резюме

Паренхиматозное кровотечение, возникающее при повреждениях печени, селезенки и почек, является одним из наиболее сложных типов кровотечений для контроля из-за его диффузного характера, отсутствия четкой точки кровотечения и высокой вероятности коагулопатии. Несмотря на широкое применение механического гемостаза, электрокоагуляции и тампонады, их эффективность остается ограниченной при глубоких или мультифокальных повреждениях паренхимы. В связи с этим использование различных видов местных гемостатических губок приобретает все большую значимость как в экстренной, так и в плановой хирургии. Цель исследования – оценить эффективность гемостатических губок в лечении паренхиматозного кровотечения посредством анализа доклинических и клинических работ, посвященных различным категориям местных гемостатических материалов. Был проведен комплексный обзор доклинических и клинических исследований, систематических обзоров и метаанализов, оценивающих гемостатические губки животного, растительного и синтетического происхождения при паренхиматозных кровотечениях. Поиск выполнялся в базах PubMed, MedLine и Scopus за период 2019-2025 гг. Всего было выявлено 213 публикаций; 119 были исключены по заранее определенным критериям (дублирование, недостаточный уровень доказательности, отсутствие данных о паренхиматозных органах). В окончательный анализ включены 94

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исследования, соответствующие критериям отбора. Большинство работ демонстрируют, что использование местных гемостатических губок значительно сокращает время достижения гемостаза, уменьшает интраоперационную кровопотерю и снижает риск повторного кровотечения по сравнению со стандартными методами. Наиболее изученными материалами являются губки на основе коллагена, желатина, окисленной целлюлозы, фибрина и хитозана, каждая из которых обладает собственным механизмом действия. Сравнительные исследования показывают, что, несмотря на сопоставимую клиническую эффективность многих типов губок, оптимальный выбор зависит от особенностей раны и интраоперационных условий. В настоящее время доступен широкий ассортимент гемостатических губок для лечения паренхиматозного кровотечения, однако универсального идеального материала не существует. Представленный обзор подтверждает, что местные гемостатические губки являются оправданным и клинически эффективным дополнением к стандартным методам гемостаза.

Ключевые слова: гемостатические губки, местный гемостаз, паренхиматозное кровотечение, коллаген, желатин, хитозан.

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