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Species-Specific and Wound-Specific Models in Preclinical Wound Healing: A Comprehensive Review

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ABSTRACT

Objective

To thoroughly assess the various animal and experimental wound models used in wound healing research, this systematic review summarizes the species/strains, benefits, drawbacks, and methodological foundations for choosing suitable models.

.Methods

Databases such as PubMed, Scopus, Web of Science, and Google Scholar were searched for relevant studies until December 2025. The PRISMA guidelines were followed in the screening of studies describing animal species used for wound healing or experimental wound creation. Full texts that met the criteria were qualitatively synthesized**.**

Results

Eight major animal species (mouse, rat, rabbit, guinea pig, pig, dog, zebrafish, and horse/sheep in restricted settings) and eight widely used wound models (incision, excision, partial-thickness, full-thickness, burn, diabetic, subcutaneous implant, and rabbit ear) were identified. Each model has advantages and disadvantages in terms of skin anatomy, healing mechanisms, genetic tractability, and suitability for specific research outcomes.

Conclusion

The choice of animal and wound models should be based on research objectives. Rodents are more economical, but are mainly cured by contraction, whereas pigs are the closest to humans in terms of structure. Specialized models, such as those used for diabetic wounds or rabbit ears, address specific pathophysiological conditions. As there is no universal model, researchers should match the depth of the wound, healing mechanism, and physiological relevance to human conditions when designing their studies.

KEYWORDS

Wound healing; Animal wound models; Full-thickness wound model; Excision wound model; Incision wound model; Burn injury model; Diabetic wound model

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INTRODUCTION

STATEMENT OF PURPOSE

The authors emphasizes that the factual molecular mechanism of wound healing cannot be replicated by using animal models because no single species or experimental wound model is suitable for the study. The author also accentuates the importance of selecting appropriate wound healing models according to the specific research question and objectives set by the researchers. The author covers the advantages and disadvantages of different species, including zebrafish, pigs, rabbits and rodents, as well as wound healing models (e.g. burns, incision, wounds and diabetic wounds) in terms of translational utility, costs, wound healing processes and anatomical similarity. Although pigs are more anatomically similar, they have disadvantages such as higher costs, scarcity of reagents and ethical limitations which prevent them from being used as laboratory animals. Rodent models, on the other hand, are more reasonably priced and genetically manipulable, but differ significantly from human wound healing, since rodent wounds are primarily healed by contraction. The main disadvantage of specialized wound healing models is that they only address specific pathophysiological conditions and are not able to accurately replicate the complexity of chronic human wounds. To improve reproducibility and translational validity, the authors support the use of several complementary models, standardized procedures, and multidisciplinary approaches. In order to fill in the gaps in preclinical research, they also support incorporating human-relevant systems, such as ex vivo skin and bioengineered alternatives. By focusing the main question on improving model selection and methodological rigor to increase the translational relevance of preclinical wound healing research with the ultimate goal of accelerating the development of effective treatments for human woundsthis viewpoint adds to a statement of purpose.

Inflammation, proliferation, and remodeling are part of the complex, multistep physiological process of wound healing[1-10]. Due to ethical and practical constraints, animal models are essential for understanding wound biology and evaluating new therapeutic approaches[11-20]. However, selection of the best model may be difficult given the wide variety of animal species and types of injuries[1-15]. This review summarizes the advantages and disadvantages of animal models and wound-making methods that are commonly used in preclinical wound research[16-22]. The aim was to increase the translational validity of future studies and guide the selection of logical models[22-36].

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AIMS

The authors set out the specific objectives which can be classified as substantive, theoretical and methodological for preclinical wound healing research:

Substantive Aims:

1. To enhance the translational use of preclinical wound models in healing research by choosing animal species and wound models that most closely resemble the processes involved in human wound healing.
2. To address the intricate pathophysiology of chronic human wounds by integrating with specialized models and employing various supplementary animal models (e.g., burns, diabetic, and rabbit ears) that bear a resemblance to particular pathological conditions.
3. To improve the biological and clinical validity of experimental models to accelerate the development of effective new treatments and their evaluation in both acute and chronic human wounds.

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Theoretical Aims:

1. To deepen the understanding of biological, anatomical and immunological differences between humans and commonly used animal models and to highlight how these differences influence the mechanisms of wound healing (e.g. contraction-driven healing in rodents versus granulation and re-epithelialization in humans).
2. To conceptualize wound healing as a multifaceted complex process that requires models that capture different stages and mechanisms rather than relying on a single model.
3. To use model selection and methodological rigor, the main research question how to best approximate human wound healing in preclinical settings will be developed.

Methodological Aims:
Standardizing wound creation methods and experimental procedures will increase reproducibility and comparability amongst all labs involved in wound healing research.

1. To promote the validation of wound models prior to treatment evaluation, making sure that the goals of the study are in line with the physiological relevance of the model.
2. To encourage the application of interdisciplinary methods and the incorporation of human-relevant systems in wound healing studies, such as ex vivo human skin and animal models for bioengineered skin substitutes, in order to close the gap between translational and clinical research.
3. To promote the use of several complementary models to better represent the complexity of human wound healing, rather than relying on one model alone

All the above points indicate a methodologically sound, strategic and integrated approach to preclinical wound healing research, balancing biological fidelity, methodological consistency and translational applicability.
To reinforce the significance of the main research question, which is how to optimize the selection and application of experimental models of wounds in preclinical research with an eye toward boosting translational relevance, the authors draw attention to the significant gaps and difficulties in this field. According to the author, no single wound healing model can precisely replicate how human wounds are healed in any one species due to basic biological, anatomical, and immunological variations. Rodent healing is primarily by contraction, whereas human healing is primarily by granulation and re-epithelialization, despite genetic tractability and cost-effectiveness. Despite their limitations due to species-specific histological differences, cost, and ethical considerations, larger mammals like pig species provide a more comparable anatomical structure.
These species-specific limitations and the methodological difficulties present in different wound models such as incision, excision, burn, and diabetic wounds each with unique benefits and disadvantages impacting reproducibility and clinical translation are documented in pertinent literature cited by the authors. They also highlight the intricacy of chronic wounds in humans, which specialized models (e.g., models of diabetes or burns) only partially address.
The authors argue for a strategic, multidisciplinary approach to increase the predictive power of preclinical studies by combining insights from several complementary models, standardized methodologies, and human-relevant systems like ex vivo skin and bioengineered substitutes. This strategy seeks to close the translational gap and hasten the creation of potent treatments for the healing of human wounds.
This justification is based on the findings of the systematic review and supported by extensive previous research cited in the systematic review, which stresses the need for methodological rigour and model selection consistent with the specific research objectives to address the complex biology of human wounds.
In order to maximize translational relevance, the authors highlight the importance of selecting the best wound models and utilizing animal species and experimental wound models. This helps to position the value of their work in preclinical wound healing research. Because of the biological, anatomical, and immunological differences that exist naturally, the author emphasizes that no single animal model, wound type, or species can accurately mimic human wound healing. The significance of matching model selection to particular research goals is emphasized here in order to increase the validity and generalizability of results.
Their value proposition emphasizes a methodical, strategic approach that incorporates human-relevant systems like ex vivo skin and bioengineered alternatives, as well as several complementary animal models. To improve reproducibility and translational accuracy, they support standardized procedures and model validation. The authors frame their contribution as offering a nuanced, evidence-based framework for model selection that strikes a balance between biological fidelity, methodological rigor, and practical feasibility by recognizing the limitations of common models, such as contraction-driven healing in rodents versus human granulation and re-epithelialization, or the cost and ethical constraints of pig models.
The authors work aims to ultimately to bridge the translation gap in wound healing research and to accelerate the development of effective treatments for human injuries by promoting a paradigm of research that is multi-disciplinary and model-based. This value-based approach supports the development of preclinical research beyond reliance on single, limited models towards complex, context-specific experimental paradigms.

The aim of the authors' work is ultimately to bridge the translation gap in wound healing research and to accelerate the development of effective treatments for human wounds by promoting a multi-disciplinary and model-based research paradigm. This value-based approach supports the development of preclinical research beyond reliance on single, limited models to a more complex experimental paradigm that is tailored to the specific context.

In order to accomplish the substantive, theoretical, and methodological goals in preclinical wound healing research, the authors synthesize the literature and identify a number of general issues and problems that need to be addressed.

Substantive Issues:

1. No single species or wound model fully mimics the healing of human wounds due to basic biological, anatomical and immunological differences (e.g. contraction-driven healing in rodents versus granulation and epithelialization in humans).
2. Specialized models (e.g., diabetes, burns) only partially recapitulate the complexity of chronic human injury, which limits translational utility.
3. The use of anatomically closer models such as pigs is limited by high costs, ethical constraints and species-specific histological differences.

These issues highlight the need for optimal model selection to better represent the pathophysiology of human wounds and to improve the clinical relevance of findings.

Theoretical Issues:

Understanding how different species heal is essential, as differences in skin structure and immunological responses influence wound healing dynamics and the efficacy of treatments. Consideration of wound healing as a complex process requiring several complementary models rather than one model to account for different stages and mechanisms. Despite the limitations of models, it is difficult to formulate research questions and hypotheses that accurately represent the biology of human injury.

Methodological Issues:

Comparability is difficult and reproducibility poor due to the lack of standardization of wound formation techniques in animals and the lack of standardization of experimental protocols, thus reporting is poor in many studies. Some changes in wound healing techniques, such as the use of splints to prevent contracture healing, may cause confounding factors such as changes in body response to foreign substances that alter biomechanical properties that are difficult to translate. Interpretation is particularly difficult in a diabetes model such as a genetic versus chemical-induced diabetes, due to inconsistent hyperglycaemia and metabolic status in this model. Artificial wound environments (e.g. subcutaneous implant models) are not as complex as open wounds, which limits their clinical relevance. There is an urgent need to validate models before using them for testing, to integrate systems relevant to humans (ex vivo skin, bioengineered surrogates), and multidisciplinary approaches. The use of multiple complementary models is recommended to better capture the complexity of human wound healing and to increase translational validity.

METHODS

Search Strategy

A comprehensive search was conducted across PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar until December 2025 using the keywords“animal model,” “wound healing,” “experimental wound,” “incision,” “excision,” “partial thickness,” “full thickness,” “burn model,” “diabetic wound,” “rabbit ear model,” “PVA sponge,” and “zebra fish wound.”

Eligibility Criteria

Inclusion:

- Studies describing animal species used for wound healing.
- Studies detailing wound creation techniques.
- Reviews and original studies on wound-model methodology.

Exclusion:

- In vitro studies only.
- Non-cutaneous wound models.
- Studies that did not provide methodological details

Selection

The screening was carried out in two phases.

- Title and abstract screening
- Full-text evaluation

RESULTS

PRISMA Flow Diagram (Narrative Summary)

- Records identified: 219
- Records screened: 219
- Full texts assessed: 40
- Studies included in final synthesis: 36

SECTION 1: ANIMAL MODELS USED IN WOUND HEALING RESEARCH

Table 1

Species/Model	Common Strains	Skin Type	Healing Mechanism	Advantages	Limitations
Mouse[1-36]	Swiss albino, C57BL/6, BALB/c, knockout models	Loose, thin skin	Contraction	Small; cheap; many genet	Different anatomy; contraction dominant; thin skin issues; immunology differs
Rat[1-36]	Sprague‌â Dawley	Loose skin	Contraction	Larger wounds possible; low cost; strong historical dataset	Non-human-like anatomy; limited genetic tools; fewer reagents
Rabbit[1-36]	Not strain-based (ear model important)	Loose skin (ears: tight)	Contraction except ears	Moderate cost; ear model avoids contraction; multiple wounds per	Limited genetic tools; limited antibodies
Guinea Pig[1-36]	Few strains, no	Loose skin	Contraction	Moderate cost; vitaminC deficiency models collagen studies	Unpopular; long gestation; small litters; limited strains
Pig[1-36]	Yorkshire, Landrace,	Tight human-like skin	Partial: epithelialization; Full: contraction + granulation	Most human-like; large wounds; best translational model	High cost; gland differences; lower vascular density
Zebrafish[136]	Various lab strains	Aquatic epidermis	Re-epithelialization + granulation	Very cheap; easy genetics; clear sequential phases; great for screening	Limited reagents; not fully dermatology-ready
Dog[1-36]	Various breeds (1â€“10 yrs)	Dog skin	Variable	Large surface; good for clinical & translational relevance	Ethical limits; high cost

SECTION 2: EXPERIMENTAL WOUND MODELS

Table 2

Model	Species	Method	Advantages	Limitations	Applications
Incision Wound Model[1-36]	Rodents, rabbits, dogs	Linear full-thickness cut through epidermis, dermis, and	Ideal for biomechanical analysis (tensile strength)	Small wound volume limits histological assessment	Tensile strength testing; Evaluating sutures and dressings; Studying scarring >65 days
Excision Wound Model[1-36]	Mouse, rat, rabbit, hamster, pig	Circular or square full-thickness skin removal	Tissue sample for collagen/cytokines/RNA;	Splints to prevent contraction may dislodge	Topical testing; Granulation and re-epithelialization studies
Partial-Thickness Wound Model[1-36]	Various (dermatome-based)	Handheld or electric dermatome	Minimal contraction; Reproducible area; Applicable to humans & animals	Surface wound only; Difficult on thin-skinned mice	Topical evaluation; Environmental wound studies
Full-Thickness Wound Model[1-36]	Rodents, rabbits, pigs	Removal of epidermis and dermis using biopsy punch or scalpel	Large wound volume; Histological profiling; Hypertrophic scar research	High bleeding and infection risk	Collagen analysis; Granulation tissue area; Epithelialization rate
Burn Wound Model[1-36]	Rodents, rabbits, pigs	Scald, flame, or heated metal burns	Thermal injury insights; Measures	Large necrotic zones; Complex healing stages	Burn therapy evaluation; Histology; MPO assays
Diabetic Wound Model[1-36]	db/db mice,	Metabolic induction of diabetes	Simulates impaired healing; Good for GF/complication studies	Doesn't fully mimic human diabetes; Hyperglycemia varies	Chronic/infected wound research; Drug evaluation
Subcutaneous Implant Models[1-36]	All species depending on material	PVA sponge or	Easy wound fluid collection; Good collagen yield; Cross-species use	Immune response risk; Sponge variability;	Connective tissue formation; Inflammatory markers; Angiogenesis
Rabbit Ear Model[1-36]	Rabbit	Full-thickness wounds applied to ear cartilage	No contraction; Human-like epithelialization; Multiple wounds per ear	Limited	Hypertrophic scars; Angiogenesis; Epithelialization

CRITICAL DISCUSSION

Species-Related Limitations in Preclinical Wound Healing Research

This analysis raises the important question of how the results of experimental animal studies can be extrapolated to clinical practice to predict clinical outcomes. This provides insight and highlights the most important biological, anatomical, and immunological differences between humans and animals. The most common models are rodent models such as mice and rats, which are well known to researchers because of their small size, ease of handling, docility, and genetic variability as well as the availability of antibody kits for immunological testing that are readily available to researchers[1-36].However, anatomical differences in animal skin, such as loose skin, dense hair coat, and healing mechanisms, are mainly due to contraction, which has a significant influence and is fundamentally different from that in humans, which limits its use in translational research. To overcome the contraction-dependent healing limitation that hinders granulation and re-epithelialization, researchers have used methods such as splinting and knockout mice and transgenic diabetic mouse models. Healing of human wounds is mainly due to granulation and re-epithelialization[1-36].

Splinter techniques introduce foreign material around the wound site, which can interfere with the healing phases, such as inflammation, cause microbial colonization, and change the biomechanics of the tissue, which can complicate the results, even if the method is designed to mimic human physiology. Similar anatomical differences in skin flexibility and contractile healing have been observed in larger mammals such as guinea pigs and rabbits[1-36].

Although the rabbit ear model eliminates contraction-dependent wound healing and allows researchers to experiment with standardized wounds, its applicability for mechanistic investigations is limited owing to the lack of reliable genetic tools and assay kits for specific species[1-36].

Despite their historical importance, guinea pigs are less used in research, and problems commonly encountered are poor breeding performance, lack of strains, and lack of transgenic systems[1-36].

Pig skin is anatomically and physiologically similar to human skin and remains the closest translational model to the gold standard because of the thickness of the skin, the distribution of hair follicles, and the skin glands. However, there are significant anatomical differences, such as fat-rich subcutaneous tissue, reduced dermal vascular density, and apocrine sweat glands, which may influence the healing and inflammation phases. The use of pigs in research is limited on a large scale because of their high costs, need for specialized equipment, and ethical considerations[1-36].

Zebra fish are highly suitable for genetic modification and high-throughput screening, but the complex interactions between dermal tissue, skin tissue, and the extracellular matrix seen in human wounds are not reproducible in zebra fish[1-36].

The highly complex overlapping integrative healing phases observed in mammals are significantly different from the sequential non-overlapping phases observed in non-avian animals. The translational differences observed in these studies are further illustrated in diabetic models[1-36].

Genetically induced diabetic db mice do not fully elucidate the multifactorial pathology of human diabetes, including macrovascular disease, neuropathy, and immunological dysfunction. However, they exhibit obesity, hyperglycemia, and delayed recovery. Chemically induced diabetes in animal models produces variable hyperglycemia levels that require individual monitoring, which interferes with statistical results and reduces the reproducibility of the study. Collectively, these animal models have limitations in that no single animal model is capable of fully replicating human wound biology, which requires careful interpretation of efficacy data and the use of additional models[1-36]..

Model-Related Limitations in Experimental Wound Healing Studies

The models developed have inherent methodological limitations that may affect the validity and reproducibility of the research; it is also difficult to compare the data. Incision models are useful for the study of biomechanical properties, such as tensile strength and collagen deposition; however, they provide a minimum volume of wound, limit detailed biochemical analysis, and do not mimic complex wounds that are encountered clinically[1-36].

Excision models allow evaluation of granulation tissue, epithelialization, and inflammatory biomarkers; however, the results are influenced by splint displacement, extraneous effects due to the splint causing inflammatory reactions, and the depth of the wound, particularly in small animals with sparse skin. Although easily standardized, partial-thickness wounds do not involve deeper dermal components such as fibroblast-mediated matrix deposition,

angiogenesis, or infiltration of immune cells. Therefore, they are not adequate for evaluating treatments that target dermal remodeling and deep tissue regeneration[1-36].

Full-thickness wounds mimic clinically significant tissue loss but include significant bleeding, fluid loss, and increased risk of infection, which may change the inflammatory kinetics and healing outcomes independently of the intervention. Similarly, burns produce large areas of necrosis and ischemia, creating a healing environment that is very different from that of trauma wounds, which limits their relevance to non-thermal injuries. Although diabetic wound models are essential for the study of impaired wound healing, they differ in their underlying pathology, duration of diabetes, metabolic status, and inflammatory response, which makes it difficult to compare them with one another. Moreover, human diabetic wounds are chronically colonized, often ischemic, and affected by comorbidities, characteristics that are not fully reproducible in animal models of diabetes[1-36].

Subcutaneous implant models, such as PVA sponge and ePTFE tube, allow for a convenient evaluation of granulation tissue and inflammatory markers, but the limitation is that they create an artificial wound environment lacking the structural, biomechanical, and microbiological complexity of open wounds. Variations in collagen deposition, the risk of immunological reactions, and implant migration further complicate the reproducibility of the study[1-36].

Overall, each animal model has its limitations, which require careful selection of models, standardization of techniques, and validation of the wound model before treatment can be transferred to clinical use[1-36].

CONCLUSION

Animal models are essential tools for the study of wound healing biology and evaluation of new therapeutic agents. However, the findings of this review highlight that no single animal species or wound model can accurately reproduce the healing process of human skin. Rodents provide genetic manipulation and cost-effectiveness, but they differ significantly from human physiology owing to contraction-driven wound healing.

Large mammals, in particular pigs, offer animals with anatomical similarities, but are limited by costs, ethical considerations, specific histological differences and lack of immunological testing. Specialized models, such as those for burns, diabetic wounds, and subcutaneous implants, address specific research questions, but do not deal with the complex biology of human chronic wounds. In view of these constraints, future research should highlight the use of several complementary models rather than relying on one model alone to assess a single species or injury. Enhanced reproducibility across laboratories requires standardization and improvement of procedures. Examples of systems relevant to humans that should be included are ex vivo human skin, cell culture and complex bioengineered skin substitutes. Development of larger and more accurate animal models that closely mimic chronic wound pathophysiology. Consistency in the experimental use of multiple species and multidisciplinary approaches will increase the reliability and translational relevance of preclinical wound healing research and ultimately accelerate the development of effective treatments for both acute and chronic wounds in humans.

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