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EDITORIAL

The biological imperative of cutaneous wounds: tissue repair

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Although often used by the lay public to describe cutaneous wound closure, wound healing more accurately refers to the goal of maximal restoration of spirit, psyche, physiology, and function following tissue injury. This goal may be achieved through either tissue repair or tissue regeneration. Both result in wound closure, but in humans, closure occurs almost exclusively via repair: a process characterized by scar formation rather than restoration of native architecture.[1] True tissue regeneration remains an aspirational goal.

Tissue repair, the predominant mechanism in adult humans, is an efficient yet imperfect process that prioritizes rapid closure over anatomical restoration. It proceeds through four overlapping phases. Hemostasis initiates the process by arresting bleeding, followed by inflammation to clear debris and pathogens. The proliferative phase then fills the wound defect through granulation tissue formation, contraction, and epithelialization. Finally, remodeling organizes and strengthens the newly formed tissue as the scar matures.[2]

The hallmark of tissue repair is scar formation: the deposition of collagen that restores tissue integrity but not specialized function.[3] This process follows a consistent biological sequence: it may be normal or delayed, but cannot be accelerated. Whether a wound heals by primary intention (surgical closure) or secondary intention (spontaneous healing), the difference lies primarily in the extent of scarring.

In contrast, tissue regeneration restores both the structure and function of the original tissue. The classic example is the Axolotl salamander, which regenerates a fully functional limb or tail rather than forming a scar.[4] Humans lack this capacity; composite tissues such as limbs and digits do not regenerate (*Figure 1*). Repair restores continuity, whereas regeneration restores identity.

The limitations of human regeneration are evident in healed skin and soft-tissue wounds. While the epidermis reforms, deeper dermal appendages, such as eccrine and apocrine glands and hair follicles, are permanently lost and replaced by a collagenous matrix.[5] Consequently, the repaired tissue achieves only 70–80% of the tensile strength of uninjured skin.[6]

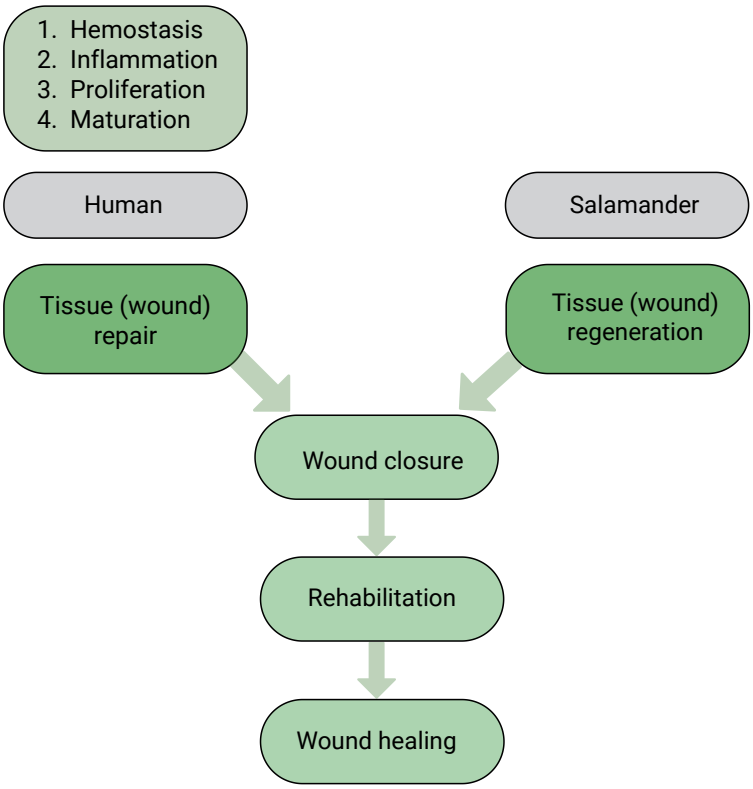

FIGURE 1 | The process of tissue repair and tissue regeneration.

In summary, wound healing encompasses both repair and regeneration, yet in humans, it is primarily a reparative process. Through scar formation, tissue repair rapidly restores barrier integrity and function, but sacrifices the structural and functional fidelity of native tissue. This distinction underscores the biological trade-off between survival through repair and the unattained ideal of proper tissue regeneration.

All human cutaneous wounds heal by tissue repair. Whether it be cellular, acellular and matrix-like products (CAMPs), negative pressure, oxygen therapies, or technologies yet to be discovered, these adjuncts are intended to aid the orderly progression of wounds through the phases of tissue repair. It is through tissue repair that we obtain the goal of wound healing: spiritual, psychological, physiological, and functional. One day, through advances in biomedical engineering, we hope to achieve the aspirational goal of tissue regeneration.

Conflicts of interest

The authors declare no conflicts of interest.

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