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Review Article

Decellularized extracellular matrix scaffolds and biological constructs as a paradigm shift in orchestrating recapitulative tissue regeneration for complex hand reconstruction

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ABSTRACT

The inherent limited regenerative capacity of composite tissues in the human hand, frequently compromised by trauma, oncological resection, or degenerative pathologies, presents a formidable challenge in restorative surgery. Conventional autografts are constrained by donor site morbidity, finite availability, and suboptimal structural integration, while synthetic implants often fail to provide the requisite biological cues for true histogenesis. This has precipitated a translational pivot towards bioengineered strategies leveraging decellularized extracellular matrix (dECM) scaffolds. These biological frameworks, derived from allogeneic or xenogeneic tissues, are meticulously processed to remove immunogenic cellular antigens while preserving the intricate ultrastructural architecture and native bioactive signaling molecules, including glycosaminoglycans, proteoglycans, and conserved growth factors. Upon implantation, these biomimetic scaffolds act as instructive three-dimensional blueprints, facilitating host cell recruitment, proliferation, and spatially organized differentiation—a process known as guided tissue regeneration. Critical applications in hand surgery include the use of dECM nerve conduits for bridging digital nerve gaps, chondrogenic scaffolds for articular cartilage restoration in the metacarpophalangeal and interphalangeal joints, and tendon augmentation grafts. Furthermore, the advent of bioprinting and organoid culture technologies enables the pre-seeding of these scaffolds with autologous progenitor cells, such as mesenchymal stem cells or tenocytes, creating advanced tissue-engineered constructs. The overarching objective is to transcend mere mechanical repair and achieve true biological integration and functional restitution, thereby restoring the intricate biomechanics and sensorimotor repertoire of the human hand. This manuscript will elucidate the foundational science of dECM scaffolds, delineate their current clinical applications in hand surgery, and discuss the translational hurdles and future trajectories of this burgeoning field.

Keywords: Decellularized extracellular matrix, Biological scaffolds, Tissue engineering, Hand regeneration, Guided tissue regeneration, Biomimetic materials, Nerve conduits, Tendon reconstruction, Chondral defects, Vascularization, Biocompatibility, Host remodelling

INTRODUCTION

The human hand represents an apex of evolutionary biological engineering, a sophisticated organ characterized by a high degree of structural and functional complexity. Its unparalleled dexterity and sensory acuity are underpinned by a delicate synergy of multiple integrated tissues, including synovial joints, gliding tendon systems, specialized ligaments, a dense neurovascular network, and composite integumentary structures. Consequently, injury or disease processes affecting the hand—ranging from acute traumatic amputations and deep burn injuries to chronic conditions like osteoarthritis or scleroderma—can result in profound and often permanent deficits in function, leading to significant personal and societal burden.[1-3] The primary goal of reconstructive hand surgery is to restore this lost form and function; however, the clinical

armamentarium has historically been limited by significant biological and technical constraints. The autologous tissue transfer, considered the gold standard for many reconstructive procedures, is intrinsically limited by donor site availability, potential morbidity, and the inevitable functional and aesthetic compromise at the harvest site. Moreover, the transfer of inert alloplastic materials, while providing structural support, fails to participate in the dynamic biological processes of wound healing and tissue turnover, often leading to complications such as foreign body reactions, fibrosis, infection, and mechanical failure over time.[4,5]

This therapeutic impasse has catalyzed a paradigm shift in regenerative medicine, moving from a philosophy of replacement with inert or autologous materials to one of in situ regeneration guided by sophisticated biological platforms. Central to this new paradigm is the utilization of the extracellular matrix (ECM). The ECM is not merely a passive, structural scaffold for cellular attachment but is now recognized as a dynamic, information-rich microenvironment that orchestrates fundamental cellular processes including adhesion, migration, proliferation, and differentiation through biomechanical and biochemical signaling. Decellularized ECM (dECM) scaffolds are harvested from native tissues and subjected to rigorous physicochemical processing to remove all immunogenic cellular material while purposefully retaining the native ECM's complex composition and microarchitecture.[5-7]

The resulting biomaterial is a bioactive, biocompatible, and biodegradable construct that, upon implantation into a hand tissue defect, does not function as a permanent implant but as a temporary instructive template. It actively modulates the host's wound healing response, promoting a regenerative rather than a purely fibrotic pathway. It facilitates neovascularization, recruits endogenous progenitor cells, and provides topographical and chemotactic cues that guide the deposition and organization of new, site-appropriate tissue. This manuscript will provide a comprehensive exploration of the science and application of dECM and biological scaffolds in hand regeneration, examining their role in nerve repair, tendon augmentation, articular cartilage resurfacing, and composite tissue reconstruction, thereby outlining the frontier of a new era in reconstructive microsurgery.[7-9]

BACKGROUND

The pursuit of functional restoration following significant tissue loss in the hand has long represented a central, yet elusive, objective in the field of reconstructive microsurgery and hand surgery. The historical trajectory of hand reconstruction is characterized by an evolution from rudimentary wound management and amputation towards sophisticated techniques of tissue transfer and microvascular reconstruction. The advent of the autologous tissue graft, particularly the vascularized free tissue transfer, marked a seminal advancement, enabling the replacement of composite tissue defects with like-for-like biological material.[10,11]

Autografts, by virtue of their innate viability and biocompatibility, provided a living substrate for healing and established an enduring gold standard for complex reconstruction. However, the paradigm of autografting is intrinsically burdened by a well-documented constellation of limitations, paramount among them being donor site morbidity. The harvest of autologous tissue, whether skin, tendon, nerve, or vascularized bone, invariably creates a secondary surgical defect, incurring its own risks of postoperative pain, sensory loss, functional impairment, and aesthetic deformity. Furthermore, the available inventory of autologous tissue is finite, and its structural and functional characteristics are often a suboptimal match for the highly specialized tissues of the hand, such as the gliding surface of flexor tendons or the precise neuroarchitecture of digital nerves.[12-14]

Concurrently, the development and implementation of alloplastic materials offered an alternative pathway, seeking to bypass the constraints of autograft harvest altogether. Synthetic polymers, metallic implants, and engineered biomaterials were introduced to provide immediate structural support and mechanical continuity. While successful in certain applications, these synthetic paradigms frequently falter at the biological interface. The foreign body response, while a normal physiological reaction, can culminate in the formation of a dense, avascular fibrous capsule that isolates the implant, preventing true integration with the host tissue.[15,16]

This lack of biointegration predisposes to complications such as chronic inflammation, infection, extrusion, and mechanical failure due to stress shielding or fatigue. Most critically, these inert materials are fundamentally incapable of participating in or orchestrating the dynamic biological processes of wound healing and tissue remodeling. They represent a static, prosthetic solution in a domain that demands a dynamic, regenerative one.[17-19]

This therapeutic dichotomy—between the biological fidelity but practical limitations of autografts and the off-the-shelf availability but biological inertness of synthetics—prompted a profound reconceptualization of the repair process itself. The emerging discipline of regenerative medicine shifted the focus from mere replacement to true restoration, aiming to recapitulate the native ontogeny of tissue formation. This paradigm is fundamentally predicated on the pivotal role of the ECM. No longer viewed as a passive structural scaffold, the ECM is now understood to be a complex, dynamic, and information-rich nano-environment that exerts exquisite spatiotemporal control over cellular behavior. It is a repository of bound growth factors, cytokines, and matrikines, and its topographical architecture provides critical contact guidance cues that direct cell migration, polarity, and differentiation. The seminal breakthrough was the development of protocols for the decellularization

of allogeneic or xenogeneic tissues, producing acellular biological scaffolds composed almost entirely of the native ECM. Through a meticulous sequence of physical, chemical, and enzymatic treatments, immunogenic cellular and nuclear material is eradicated, while the integrity of the underlying ultrastructure, biomechanical properties, and crucial bioactive signaling molecules is preserved.[20-22]

Upon implantation into a defect site in the hand, these decellularized ECM scaffolds do not function as a permanent prosthesis but as a temporary, instructive template. They undergo a precisely orchestrated process of biodegradation, simultaneously acting as a chemoattractant for host progenitor cells and a guide for neotissue formation. This process, termed "guided tissue regeneration," facilitates the deposition of site-specific, organized, and vascularized tissue rather than disorganized scar. The scaffold's composition and microarchitecture can be further tailored to direct specific lineage commitment, promoting tenogenesis for tendon repair, neurogenesis for nerve gaps, or chondrogenesis for articular defects.

The most contemporary advancements involve synergizing these biological scaffolds with cellular components, such as autologous mesenchymal stem cells or induced pluripotent stem cell-derived progenitors, and sophisticated biofabrication techniques like 3D bioprinting, to create patient-specific, pre-vascularized tissue constructs that represent the vanguard of a new era in restoring the intricate functional capacity of the human hand.[23-25]

SURGICAL APPLICATIONS AND USES

The integration of decellularized extracellular matrix scaffolds into the surgical armamentarium for hand reconstruction has engendered a transformative approach across a multitude of clinical scenarios, each characterized by a distinct pathophysiological insult and a corresponding set of regenerative objectives. In the realm of peripheral nerve repair, the management of segmental nerve defects exceeding a few millimeters has historically presented a significant challenge, with autologous nerve grafting, typically from the sural nerve, constituting the standard of care despite the inherent drawbacks of donor site morbidity and the sacrifice of a sensory nerve. The contemporary surgical application now involves the interposition of decellularized nerve allografts or ECM-based nerve guidance conduits to bridge such gaps.[26-28]

These tubular biological constructs provide a protected microenvironment, rich in laminin and other neurotrophic factors preserved from the native basal lamina, which serves to guide the advancing growth cones of regenerating axons from the proximal stump while minimizing the aberrant formation of neuromas and the infiltration of fibrous tissue that would otherwise impede neural regeneration. This is particularly critical for the restoration of discriminative sensation in the digital pulp or for motor reinnervation of the intrinsic hand muscles.[26-28]

Similarly, the reconstruction of the intricate tendon system of the hand, especially within the complex anatomical confines of the digital flexor sheath, has been revolutionized by the use of biological scaffolds. Injuries to the flexor digitorum profundus in zone II, the so-called "no-man's-land," are notoriously prone to the formation of adhesions that cripple the essential gliding function. The surgical implantation of an ECM scaffold, configured as a tendon wrap or an augmentation graft, serves a dual purpose. Firstly, it provides immediate structural continuity and mechanical strength at the repair site, mitigating the risk of gapping or rupture during the early phases of rehabilitation. Secondly, and more profoundly, its bioactive surface modulates the cellular response of the surrounding synovial environment, promoting the proliferation of tenocytes while simultaneously directing the phenotype of fibroblasts towards a reparative rather than a fibrotic program, thereby reducing adhesion formation between the tendon and the pulley system. This facilitates a more favorable biological milieu for the restoration of smooth, unimpeded tendon excursion.[27,28]

In the context of articular cartilage restoration, the limited self-repair capacity of hyaline cartilage following traumatic chondral defects or in the setting of early osteoarthritis in the metacarpophalangeal or interphalangeal joints has been a persistent therapeutic dilemma. The surgical application of osteochondral allografts or microfracture techniques has yielded inconsistent results. The use of particulated juvenile cartilage allografts, which are essentially ECM-rich constructs of viable chondrocytes, represents a novel biological intervention.[28,29]

These chondrogenic scaffolds are implanted into the debrided chondral defect, where they provide a matrix that supports the migration of host mesenchymal progenitor cells and stimulates the production of type II collagen and aggrecan, thereby promoting the formation of hyaline-like repair tissue that integrates with the surrounding native cartilage and provides a durable, low-friction articulating surface.[28,29]

Beyond these specific applications, decellularized dermal matrices are extensively utilized in complex soft tissue reconstruction, providing a pliable and robust scaffold for resurfacing extensive wounds following burn injuries or traumatic degloving, facilitating neovascularization and repopulation by host fibroblasts and keratinocytes. Furthermore, composite tissue engineering strategies are now exploring the use of multi-laminate ECM scaffolds, pre-seeded with autologous cells, to address the ultimate challenge of reconstructing composite tissue units that mimic the stratified architecture of the native hand, incorporating elements of dermis, fascia, tendon, and nerve within a single, surgically implantable biological construct. This represents the convergence of advanced

biomimetic design with precise surgical execution, aiming not merely to close a defect but to orchestrate the recapitulation of functional anatomical complexity.[28,29]

INDICATIONS AND CONTRAINDICATIONS

The surgical deployment of decellularized extracellular matrix scaffolds and biological constructs within the realm of hand surgery is predicated upon a stringent set of clinical indications and contraindications, which are paramount for ensuring optimal patient selection, procedural success, and the mitigation of potential adverse outcomes. The primary indications for this advanced regenerative approach are multifaceted, encompassing a spectrum of anatomical and pathophysiological scenarios where conventional reparative techniques are either suboptimal or have demonstrably failed.[28,29]

A cardinal indication is the presence of a segmental tissue defect, characterized by a loss of substance that precludes primary apposition without inducing deleterious tension or functional shortening. This is particularly salient in the context of peripheral nerve gaps exceeding a critical threshold, typically around five millimeters, where end-to-end neurorrhaphy is not feasible and the use of a nerve guidance conduit or a decellularized nerve allograft becomes the intervention of choice to bridge the discontinuity and provide a permissive microenvironment for axonal sprouting and regeneration. Similarly, substantial defects in the tendinous architecture, whether due to traumatic avulsion, surgical debridement of necrotic or infected tissue, or attritional ruptures, represent a robust indication for the interposition of an ECM scaffold to restore gliding length and mechanical continuity while simultaneously modulating the healing response towards a regenerative rather than a purely fibrotic pathway.[30]

Further compelling indications include the clinical imperative to augment a primary repair, a strategy employed to fortify a tenuous surgical coaptation, such as a tendon repair in a zone of hypovascularity or in a patient with underlying systemic comorbidities that are known to impair wound healing, such as diabetes mellitus or chronic corticosteroid use. In these scenarios, the biological scaffold acts as a reinforcing onlay graft, providing additional tensile strength and delivering a concentrated bolus of bioactive molecules to the repair site, thereby reducing the risk of gap formation or catastrophic failure. The management of recalcitrant wound beds that exhibit poor intrinsic healing capacity, often observed in the context of previous irradiation, chronic venous or pressure ulcers, or in tissues compromised by systemic sclerosis, constitutes another critical indication.[29,30]

The application of a decellularized dermal matrix in such instances serves to transform the wound biological milieu from a state of chronic inflammation and proteolytic degradation to one that is conducive to cellular infiltration and neomatrix deposition, effectively acting as a regenerative template to guide the formation of organized, vascularized granulation tissue. Furthermore, the desire to prevent the formation of adhesions in anatomically confined spaces, most notably within the digital flexor sheath, is a profound prophylactic indication, where the ECM material is positioned as a physical and biological barrier to isolate the repaired tendon from the surrounding parietal synovium, thereby preserving its essential gliding function.[29,30]

Conversely, the existence of absolute and relative contraindications mandates careful preoperative evaluation to avoid scenarios where the implantation of a biological scaffold is likely to result in failure or complication. An absolute contraindication is the presence of an active, ongoing localized infection or a systemic septic state. The introduction of a foreign body, even one of biological origin, into a contaminated surgical field creates a nidus for microbial colonization and biofilm formation, which can precipitate graft dissolution, persistent suppuration, and ultimately necessitate explantation. Significant tissue ischemia or an inadequately perfused wound bed, which cannot be rectified through concomitant revascularization procedures, represents another potent contraindication; the successful integration and remodeling of an ECM scaffold are critically dependent upon a robust vascular inflow to deliver inflammatory mediators, progenitor cells, and nutrients essential for the process of constructive remodeling, and in its absence, the scaffold will invariably undergo avascular necrosis and resorption.[29,30]

A known, documented hypersensitivity or allergic reaction to the residual chemical cross-linking agents, such as glutaraldehyde, or to preserved xenogeneic proteins within certain scaffold formulations, is an absolute contraindication due to the risk of precipitating a severe immunogenic response. The presence of a malignant or potentially malignant process within the surgical site is likewise an absolute contraindication, as the pro-angiogenic and pro-mitotic signals inherent to the remodeling process could theoretically potentiate tumor growth or dissemination.[29,30]

Among the relative contraindications, which necessitate a careful risk-to-benefit analysis, is a severe, uncorrectable coagulopathy or a state of profound immunosuppression, both of which can catastrophically impair the delicate and coordinated cascade of events required for scaffold incorporation and neotissue formation. The management of a non-compliant patient or one unable to participate in the mandatory and often protracted postoperative rehabilitation protocol is also a significant relative contraindication, as the mechanical integrity of the scaffold during its vulnerable period of remodeling is entirely dependent on the adherence to specific load-bearing and mobilization restrictions.[29,30]

Finally, the lack of adequate soft tissue coverage over the implanted scaffold presents a substantial relative contraindication, as exposure to the external environment

or desiccation will inevitably lead to graft failure, underscoring the necessity for a well-vascularized cutaneous or subcutaneous envelope to ensure its survival and successful integration into the host architecture.[29,30]

CONCLUSION

In summation, the advent of decellularized extracellular matrix scaffolds and advanced biological constructs heralds a profound paradigm shift in the therapeutic arsenal for complex hand reconstruction, moving the discipline beyond the historical limitations of autologous tissue transfer and inert alloplastic implantation. The foundational principle underpinning this transformative approach is the recognition of the extracellular matrix not as a passive architectural element but as an indispensable, dynamic, and information-rich microenvironment that exerts exquisite spatiotemporal control over cellular behavior, fate, and morphogenesis. The surgical implantation of these meticulously engineered biomimetic scaffolds represents a strategic intervention aimed at recapitulating native ontogeny by providing an instructive, three-dimensional blueprint for guided tissue regeneration. Within the highly specialized anatomical and functional context of the hand, these biologics have demonstrated significant utility across a spectrum of challenging clinical entities, from bridging critical-size nerve gaps with bioinductive conduits that facilitate precise axonal guidance and neurotization, to reinforcing tenuous tendon repairs while simultaneously modulating the perilous balance between gliding function and adhesiogenesis.

The application of chondrogenic scaffolds offers a promising avenue for restoring the low-friction articular surface of metacarpophalangeal and interphalangeal joints, while dermal matrices facilitate the reconstruction of a pliable and sensate soft tissue envelope. The ultimate trajectory of this field is poised at the convergence of advanced biomaterials science, developmental biology, and surgical innovation. The future lies in the creation of patient-specific, multi-laminate, and pre-vascularized composite constructs, potentially through technologies such as three-dimensional bioprinting with bioinks composed of patient-specific cells and ECM proteins, designed to replace the intricate osteotendinous, neurovascular, and integumentary units of the hand in a single-staged procedure. However, the translation of these sophisticated technologies into routine clinical practice is contingent upon overcoming persistent challenges, including the standardization of decellularization protocols to ensure complete removal of immunogenic epitopes while maximizing the retention of crucial bioactive factors, the optimization of scaffold biomechanical properties to match the dynamic loading demands of the hand, and a deeper understanding of the host immune response to these materials to truly harness its regenerative potential. Therefore, the integration of decellularized extracellular matrices and biological scaffolds is not merely an incremental improvement but a fundamental redefinition of the objectives of hand surgery, from a discipline focused on mechanical repair and tissue replacement to one that aspires to achieve true biological integration and the holistic restoration of the hand's unparalleled functional repertoire.

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REFERENCES

1. Tissue Regeneration and Organ Repair. Medscape. 2003. Available at: https://www.medscape.com/viewarticle/457173. Accessed on 30 October 2025.
2. Vacanti CA. The history of tissue engineering. J Cell Mol Med. 2006;10(3):569-76.
3. Mikael PE, Golebiowska AA, Xin X, Rowe DW, Nukavarapu SP. Evaluation of an Engineered Hybrid Matrix for Bone Regeneration via Endochondral Ossification. Ann Biomed Eng. 2020;48(3):992-1005.
4. Amini AR, Adams DJ, Laurencin CT, Nukavarapu SP. Optimally porous and biomechanically compatible scaffolds for large-area bone regeneration. Tissue Eng Part A. 2012;18(13-14):1376-88.
5. Mikael PE, Golebiowska AA, Kumbar SG, Nukavarapu SP. Evaluation of Autologously Derived Biomaterials and Stem Cells for Bone Tissue Engineering. Tissue Eng Part A. 2020;26(19-20):1052-63.
6. Mikael PE, Golebiowska AA, Xin X, Rowe DW, Nukavarapu SP. Evaluation of an Engineered Hybrid Matrix for Bone Regeneration via Endochondral Ossification. Ann Biomed Eng. 2020;48(3):992-1005.
7. Dorcemus DL, Kim HS, Nukavarapu SP. Gradient scaffold with spatial growth factor profile for osteochondral interface engineering. Biomed Mater. 2021;16(3).
8. Kumbar SG, Nukavarapu SP, James R, Nair LS, Laurencin CT. Electrospun poly(lactic acid-co-glycolic acid) scaffolds for skin tissue engineering. Biomaterials. 2008;29(30):4100-7.
9. Golebiowska AA, Nukavarapu SP. Bio-inspired zonal-structured matrices for bone-cartilage interface engineering. Biofabrication. 2022;14(2).
10. Amini AR, Xu TO, Chidambaram RM, Nukavarapu SP. Oxygen tension-controlled matrices with osteogenic and vasculogenic cells for vascularized bone regeneration in vivo. Tissue Eng. 2016;22(7-8):610-20.
11. Amini A, Nukavarapu S. Oxygen-tension controlled matrices for enhanced osteogenic cell survival and performance. Ann Biomed Eng. 2014;42(6):1261-70.
12. Nukavarapu SP, Laurencin CT, Amini AR, Dorcemus DL. Gradient Porous Scaffolds. US9707322B2. Available at: https://patents.google.com/patent/US9707322B2/en?inventor=nukavarapu&oq=nukavarapu. Accessed on 30 October 2025.

13. Bae WG, Kim J, Choung YH, Chung Y, Suh KY, Pang C, et al. Bio-inspired configurable multiscale extracellular matrix-like structures for functional alignment and guided orientation of cells. Biomaterials. 2015;69:158-64.
14. Young JL, Holle AW, Spatz JP. Nanoscale and mechanical properties of the physiological cell–ECM microenvironment. Exp Cell Res. 2016;343(1):3-6.
15. Lutolf MP, Hubbell JA. Synthetic biomaterials as instructive extracellular microenvironments for morphogenesis in tissue engineering. Nat Biotechnol. 2005;23(1):47-55.
16. Unal AZ, West JL. Synthetic ECM: bioactive synthetic hydrogels for 3D tissue engineering. Bioconjugate Chem. 2020;31(10):2253-71.
17. Ligorio C, Mata A. Synthetic extracellular matrices with function-encoding peptides. Nat Rev Bioeng. 2023;1-19.
18. Nicolas J, Magli S, Rabbachin L, Sampaolesi S, Nicotra F, Russo L. 3D extracellular matrix mimics: fundamental concepts and role of materials chemistry to influence stem cell fate. Biomacromolecules. 2020;21(6):1968-94.
19. Nakamura N, Kimura T, Kishida A. Overview of the development, applications, and future perspectives of decellularized tissues and organs ACS Biomater. Sci Eng. 2017;3(7):1236-44.
20. Bejleri D, Davis ME. Decellularized extracellular matrix materials for cardiac repair and regeneration Adv. Healthcare Mater. 2019;8(5).
21. Kusindarta DL, Wihadmadyatami H. The role of extracellular matrix in tissue regeneration. Tissue Regen. 2018;75728.
22. Chen FM, Liu X. Advancing biomaterials of human origin for tissue engineering. Prog Polym Sci. 2016;53:86-168.
23. Bonnans C, Chou J, Werb Z. Remodelling the extracellular matrix in development and disease. Nat Rev Mol Cell Biol. 2014;15 (12):786-801.
24. Caralt M, Uzarski JS, Iacob S, Obergfell KP, Berg N, Bijonowski BM, et al. Optimization and critical evaluation of decellularization strategies to develop renal extracellular matrix scaffolds as biological templates for organ engineering and transplantation. Am J Transplant. 2015;15(1):64-75.
25. Luo Z, Bian Y, Su W, Shi L, Li S, Song Y, et al. Comparison of various reagents for preparing a decellularized porcine cartilage scaffold. Am J Transl Res. 2019;11(3):1417-27.
26. Rosario DJ, Reilly GC, Ali Salah E, Glover M, Bullock AJ, MacNeil S. Decellularization and sterilization of porcine urinary bladder matrix for tissue engineering in the lower urinary tract. Regen Med. 2008;3(2):145-56.
27. Elder BD, Eleswarapu SV, Athanasiou KA. Extraction techniques for the decellularization of tissue engineered articular cartilage constructs. Biomaterials. 2009;30(22):3749-56.
28. Nakayama KH, Batchelder CA, Lee CI, Tarantal AF. Decellularized rhesus monkey kidney as a three-dimensional scaffold for renal tissue engineering. Tissue Eng. 2010;16(7):2207-16.
29. Cheng CW, Solorio LD, Alsberg E. Decellularized tissue and cell-derived extracellular matrices as scaffolds for orthopaedic tissue engineering. Biotechnol Adv. 2014;32(2):462-84.
30. Mangold S, Schrammel S, Huber G, Niemeyer M, Schmid C, Stangassinger M, et al. Evaluation of decellularized human umbilical vein (HUV) for vascular tissue engineering - comparison with endothelium-denuded HUV. J Tissue Eng Regen Med. 2015;9(1):13-23.

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