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Review

Use of Stem Cells in Bone Regeneration: An Updated Review

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ABSTRACT

The use of stem cells in bone regeneration has proven to be a promising area in regenerative medicine, particularly due to their differentiation and self-renewal capabilities. This article reviews the scientific advances related to the use of mesenchymal stem cells (MSCs), embryonic stem cells and induced pluripotent stem cells (iPSCs) in the treatment of bone defects. We discuss the primary sources of these cells, osteogenic differentiation methods and biomaterials used as scaffolds to facilitate regeneration. Additionally, we highlight the technical and ethical challenges that limit their large-scale clinical application. We conclude that despite significant advances, further research is necessary to ensure the safety, efficacy and commercial viability of this approach.

Keywords: Stem cells; Bone regeneration; Mesenchymal stem cells; Biomaterials; Tissue engineering

Introduction

Bone regeneration is a complex biological process that naturally occurs in response to fractures or injuries. However, in cases of large bone loss or pathological conditions, natural repair is insufficient, requiring medical interventions. Traditional therapies, such as autologous and allogeneic bone grafts, have significant limitations, including limited donor tissue availability, risk of rejection and surgical complications. In this context, tissue engineering and stem cells emerge as promising alternatives to overcome these challenges. Stem cells possess unique characteristics, such as self-renewal and differentiation into various cell types, including osteoblasts, which play a crucial role in bone formation. Mesenchymal stem cells (MSCs), derived from tissues such as bone marrow and adipose tissue, have been widely studied due to their plasticity and ease of isolation. Moreover, embryonic stem cells and induced pluripotent stem cells (iPSCs) offer therapeutic possibilities due to their high differentiation potential, although they face ethical and safety barriers.

The integration of stem cells with biomaterials also plays a fundamental role in tissue engineering. Bioactive scaffolds can mimic the bone microenvironment, promoting cell adhesion, proliferation and differentiation. Advances in 3D printing technologies have enabled the development of customized

scaffolds tailored to the specific needs of each patient. Despite these advances, significant challenges remain, including the standardization of differentiation protocols, immune response control and assessment of tumorigenicity risks. Furthermore, the translation of these technologies into clinical use faces regulatory and economic barriers.

Objectives

The objective of this article is to review the latest advances in the use of stem cells in bone regeneration, addressing the strategies, challenges and future perspectives of this approach.

Materials and Methods

A bibliographic review was conducted using articles published in the PUBMED, ScienceDirect and Scielo databases as the foundation of this study.

Discussion

The use of mesenchymal stem cells has stood out as an efficient approach for bone regeneration due to their osteogenic differentiation capacity and secretion of growth factors. Experimental studies demonstrate that the combination of MSCs with bioactive biomaterial scaffolds, such as hydroxyapatite and collagen-based composites, promotes functional bone tissue formation in animal models. The addition of growth factors, such as BMP-2 (bone morphogenetic protein), also significantly improves outcomes. Embryonic stem cells and iPSCs offer unique advantages due to their pluripotency. However, their clinical application is limited by ethical concerns, the risk of tumor formation and the complexity of differentiation protocols. Recent research explores the use of genetic editing to minimize these risks and enhance efficacy.

Another critical aspect is the interaction between stem cells and the host microenvironment. Studies suggest that controlled inflammation is essential for successful regeneration. Additionally, advances in delivery systems, such as microcapsules and nanostructures, have enabled more precise control in the release of cells and bioactive factors. Although the progress is promising, regulatory barriers remain a significant obstacle. The lack of standardization in preclinical studies hampers the translation into clinical trials. Cost-effectiveness studies are also scarce, making it difficult to integrate these therapies into healthcare systems.

Conclusion

Stem cell-based therapy represents a revolution in the treatment of bone defects, offering innovative solutions for previously untreatable conditions. MSCs, in particular, stand out for their practical viability and promising results in preclinical models. The integration with biomaterials and advanced technologies, such as 3D printing, expands therapeutic possibilities. However, challenges persist, including understanding cellular interactions in the regenerative microenvironment, controlling potential adverse effects and overcoming regulatory barriers. Advances in genetic editing and the development of more sophisticated biomaterials may offer solutions to these hurdles. It is important to emphasize that future research should focus on standardizing protocols, expanding clinical studies and evaluating cost-effectiveness. Only by addressing these challenges can we translate laboratory advances into accessible and effective treatments for the population.

References

1. Caplan AI. Mesenchymal stem cells: time to change the name! Stem Cells Translational Medicine 2017.
2. Dominici M, Le Blanc K, Mueller I, et al. Minimal criteria for defining multipotent mesenchymal stromal cells. Cytotherapy 2006.
3. Pittenger MF, Mackay AM, Beck SC, et al. Multilineage potential of adult human mesenchymal stem cells. Science 1999;284(5411):143-147.
4. Bolland F, et al. Advances in biomaterials for bone tissue engineering: A review. J Tissue Engineering 2021.
5. Mao AS, Mooney DJ. Regenerative medicine: Current therapies and future directions. Proceedings of the National Academy of Sciences 2015;112(47):14452-14459.
6. Langer R, Vacanti JP. Tissue engineering. Science 1993;260(5110):920-926.
7. Zhang J, et al. Advances in stem cell therapy for skeletal regeneration. Stem Cell Research Therapy 2016;7(1):1-10.
8. Friedenstein AJ, Petrakova KV, Kurolesova AI, Frolova GP. Osteogenic precursor cells in a bone marrow transplantation. Clinical Orthopaedics and Related Research 1966;50:31-43.
9. Griffith LG, Naughton G. Tissue engineering-current challenges and expanding opportunities. Science 2002;295(5557):1009-1014.
10. Rezwan K, Chen QZ, Blaker JJ, Boccaccini AR. Biodegradable and bioactive porous polymer/inorganic composite scaffolds for bone tissue engineering. Biomaterials 2006;27(18):3413-3431.
11. Robey PG. Stem cells near the century mark. J Clinical Investigation 2011;121(10):3793-3794.
12. Horwitz EM, Prockop DJ, Fitzpatrick LA, et al. Transplant ability and therapeutic effects of bone marrow-derived mesenchymal cells in children with osteogenesis imperfecta. Nature Medicine 20028(3):300-306.
13. Giannoudis PV, et al. The role of growth factors in skeletal repair. J Bone and Joint Surgery *2005*;87(10):1277-1289.
14. Orban JM, Wilson LB, Kofroth JA, et al. Crosslinking of collagen gels by transglutaminase. J Biomedical Materials Research 2002;60(4):547-555.
15. Lee CH, Cook JL, Mendelson A, Moioli EK, Yao H, Mao JJ. Regeneration of the articular surface of the rabbit synovial joint by cell homing: a proof-of-concept study. The Lancet 2010;376(9739):440-448.
16. Kimelman-Bleich N, et al. Bone regeneration and stem cells. Current Molecular Biology Reports, 2017;3(2):125-132.
17. Mishra R, et al. Application of scaffolds in bone tissue engineering. Materials Today: Proceedings 2022;49:195-200.