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Editorial

The Future of Regenerative Endodontics: From Biological Repair to Regenerative Medicine

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Abstract

Background: Regenerative endodontics represents a paradigm shift from conventional root canal treatment towards the biological restoration of the dentin–pulp complex. Its ultimate objective is to restore the structural organisation and physiological functions of natural dental pulp, including vascularisation, innervation, immune defence and dentin formation.

Aim: This review aims to explore recent advances, emerging technologies, clinical challenges and future perspectives in regenerative endodontics, with particular emphasis on the transition from biological repair to functional pulp–dentin regeneration.

Materials and Methods: A narrative review of contemporary literature was undertaken, focusing on stem-cell-based therapies, cell homing, tissue engineering, bioactive scaffolds, extracellular vesicles, decellularised dental pulp extracellular matrix and personalised regenerative approaches. Clinical evidence, translational research, ethical considerations and regulatory challenges were also examined.

Results: Advances in dental pulp stem-cell transplantation, endogenous cell recruitment, growth factor delivery and biomaterial development have demonstrated promising regenerative potential. Early clinical studies have reported encouraging outcomes, including sensory responses, periapical healing and dentinal wall formation. Emerging technologies such as three-dimensional bioprinting, exosomes and tissue-specific extracellular matrix scaffolds offer further opportunities for improving tissue organisation. However, predictable vascularisation, neural regeneration, effective microbial control, modulation of inflammation and restoration of normal odontoblast architecture remain significant challenges. Limited clinical evidence, protocol variability and regulatory concerns further restrict widespread clinical application.

Conclusion: The future of regenerative endodontics lies in achieving predictable, patient-specific and functionally integrated pulp–dentin regeneration rather than merely producing reparative tissue. Interdisciplinary collaboration, standardised clinical protocols and long-term clinical trials are essential to translate current scientific advances into reliable clinical therapies.

Keywords: Regenerative Endodontics; Dental Pulp Stem Cells; Pulp–Dentin Complex; Tissue Engineering; Cell Homing; Biomaterials; Functional Regeneration

Regenerative endodontics represents a paradigm shift from conventional root canal treatment towards the biological restoration of the dentin–pulp complex. Rather than merely eliminating infection and preserving the tooth, its ultimate objective is to restore the structural organisation and physiological functions of natural dental pulp, transforming endodontic treatment from tissue repair towards functional regeneration.

Recent advances in stem cell biology, cell homing, cell transplantation, tissue engineering, bioactive scaffolds and growth factor delivery have expanded the possibilities of pulp regeneration. Emerging approaches, including extracellular vesicles, exosomes, cell aggregates and decellularised dental pulp extracellular matrix, offer promising opportunities for improving tissue reconstruction. Early human clinical studies have demonstrated the feasibility of stem-cell-based pulp regeneration, providing encouraging evidence for future clinical applications.

Despite these developments, several challenges remain, including effective microbial control, regulation of inflammation, predictable vascularisation and innervation, and the formation of an organised odontoblast layer. Furthermore, achieving long-term stability, standardising regenerative protocols and establishing reliable methods for assessing functional regeneration remain essential. Ethical concerns regarding stem-cell sourcing, informed consent, biobanking, manufacturing standards and regulatory approval also require careful consideration.

The future of regenerative endodontics lies in personalised treatment approaches based on pulpal condition, residual tissue viability and patient-related factors. Interdisciplinary collaboration among endodontists, stem-cell biologists, immunologists, tissue engineers and biomaterial scientists will be crucial for translating laboratory discoveries into predictable clinical applications.

Ultimately, the success of regenerative endodontics should not be measured merely by tissue formation, root development or radiographic healing, but by the restoration of a fully functional, vascularised, innervated and immunologically competent dentin–pulp complex, preserving the tooth as a living and biologically active organ.