



GRADUATION PROJECT

Degree in Dentistry

USE OF STEM CELLS IN THE NEOFORMATION OF DENTAL TISSUE

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RESUMEN

Introducción: La odontología regenerativa se está expandiendo rápidamente y representa un gran avance. El objetivo es restaurar la vitalidad de los tejidos en lugar de simplemente reemplazarlos, como ocurre con los tratamientos dentales actuales. Entre estos avances, el uso de células madre dentales está despertando un interés creciente debido a su capacidad para diferenciarse en distintos tipos de células implicadas en la formación y reparación de los tejidos dentales. Estos avances abren nuevas perspectivas para el tratamiento de las patologías dentales; **Objetivo:** El objetivo de este estudio es identificar los diferentes tipos de células madre utilizadas en la odontología regenerativa y analizar su potencial en la neoformación de tejido dental; **Metodología:** Se realizó una revisión bibliográfica utilizando las bases de datos MEDLINE y PubMed. La búsqueda identificó 435 artículos. Tras eliminar los duplicados y aplicar los criterios de inclusión y exclusión, se seleccionaron 17 estudios y artículos completos para el análisis final; **Resultados:** El análisis de estos estudios reveló diferentes tipos de células madre dentales utilizadas en la odontología regenerativa. Las principales fueron SHED, SCAP, DPSC y PDLSC. Su uso suele asociarse con biomateriales y andamios (scaffolds) que promueven su proliferación y la formación de tejido regenerado; **Conclusión:** El uso de células madre representa una esperanza en la odontología moderna y es un enfoque prometedor para la regeneración del tejido dental que podría transformar la práctica de la odontología en el futuro. Sin embargo, aunque aún necesitan ensayos clínicos para confirmar su eficacia.

PALABRAS CLAVE: Odontología; Células madre dentales; Odontología Regenerativa; Regeneración de tejidos dentales; Ingeniería de tejidos; Biomateriales

ABSTRACT

Introduction: Regenerative dentistry represents a major advance and is rapidly expanding. Its goal is to restore the vitality of damaged tissues rather than simply replacing them, as is the case with current dental treatments. Among these advances, the use of dental stem cells is attracting growing interest due to their ability to differentiate into various cell types involved in the formation and repair of dental tissues. These advances open new perspectives for the treatment of dental pathologies; **Objective:** The objective of this study is to identify the different types of stem cells used in regenerative dentistry and to analyse their potential in the neoformation of dental tissue; **Methodology:** A literature review was conducted using the MEDLINE and PubMed databases. The search identified 435 articles. After removing duplicates and applying the inclusion and exclusion criteria, 17 studies and full-text articles were selected for final analysis; **Results:** Analysis of these studies revealed different types of dental stem cells used in regenerative dentistry. The main types identified were SHEDs, SCAPs, DPSCs, and PDLSCs. Their use is often associated with biomaterials and scaffolds that promote their proliferation and the formation of regenerated tissue; **Conclusion:** The use of stem cells represents a promising perspective in modern dentistry and a potential approach to dental tissue regeneration that could transform future dental practice. However, clinical trials are still needed to confirm their effectiveness.

KEYWORDS

Dentistry; Dental Stem Cells; Regenerative Dentistry; Dental Tissue Regeneration; Tissue Engineering; Biomaterials

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1. INTRODUCTION

1.1. Structure and alteration of dental tissues

The dental structure is a set of tissues all linked and connected to each other. The tooth is a complex organ formed by two types of tissues, soft tissues and hard dental tissues. All these tissues contribute to the overall function of the tooth and cooperate to preserve its structure and vitality. (1)

In hard tissues we find enamel, dentine, cementum and alveolar bone. Enamel represents the external part of the tooth that provides protection during stress and protects the tooth from external aggressions, whether mechanical (such as mastication) or chemical (such as acidity). It is the hardest and most mineralized tissue. Dentin is a hard but living tissue found under the enamel, it helps the enamel to protect the tooth and the overall structure of the tooth. The cementum is the tissue that covers the root and allows the anchorage of the tooth in the periodontal ligament and therefore allows its maintenance. It allows the connection of the tooth to the periodontal ligament fibers. (1)

To finish with the hard tissues, the alveolar bone serves to support and maintain the tooth within the jaw.

In the soft tissues, the pulp is a vascularized and innervated tissue located at the center of the tooth. It ensures the immune defense and plays an essential role in the formation and repair process of the tooth.

Finally, the periodontal ligament is also a soft tissue that allows the attachment of the tooth to the bone. It acts as a shock absorber during mastication and enables the transmission of mechanical forces. All these tissues constitute a very specialized biological set and guarantee several functions such as phonation, mastication and aesthetics. Their maintenance is therefore essential for oral health. (1)

However, these tissues are constantly exposed to aggressions and affected by different traumas which can be mechanical, chemical, infectious or inflammatory that impair their maintenance. These aggressions lead to alterations of these tissues.

Dental caries represent a process of destruction of hard tissues by progressive bacterial activity leading to cavity formation. These bacteria are naturally present in the mouth; they multiply and produce acids from sugars and food. They are the cause of progressive demineralization of enamel and dentin. When caries are not treated, they can lead to pulpitis as they progress to the dental pulp. It first manifests as reversible inflammation then becomes irreversible when the pulp vascularization is compromised. In advanced stages, this inflammation progresses to

pulp necrosis. The pulp then loses its vitality, including its vascular, nervous, and regenerative components such as stem cells. (2) This process is often accompanied by a secondary bacterial infection of the radicular canal and can cause periapical lesions, or even dental abscesses.

Periodontal diseases (particularly periodontitis) are diseases of infectious origin due to bacteria that affect and destroy the tissues supporting the teeth such as the periodontal ligament, and the alveolar bone. They are a major cause of the degradation of dental tissues, affecting support tissues they can lead to bone resorption and therefore to the loss of teeth. (2)

All these conditions represent a major problem in modern dentistry since these tissues cannot regenerate or have a very low regenerative capacity. They have physical but also psychological consequences, and their treatment remains a major challenge.

1.2. Conventional Restorative therapies

To treat these alterations, modern dentistry has found ways of substitution to replace, or repair lost tissues with artificial materials.

In current dental treatments, composite fillings and crowns are used to restore dentine and enamel. Implants and prostheses can replace teeth that have been lost. Endodontic treatments serve to eliminate pulp infections, and grafts can restore the supporting tissues.

However, all these treatments have limitations today since these methods remain essentially mechanical and substitutive, without biological regeneration of the lost tissue. They allow the replacement of form and function but not vitality. For example, devitalization allows the patient's tooth to remain in the mouth, maintaining its masticatory and aesthetic function, but it no longer has its vitality due to necrosis since the pulp is removed and replaced with material. It will thus become more fragile and more susceptible to fractures in the long term.

In the same way, dental implants are considered a great revolution in dentistry to replace lost teeth, but they do not reproduce the biological complexity of a living organ since they have several limitations. (3) (4)

Regarding periodontal treatments, there are two types of treatments: surgical and non-surgical treatments aimed at restoring the supporting tissues, such as cementum, periodontal ligament and alveolar bone. Different techniques have evolved to treat them, whether with bone grafts or the use of guided regeneration membranes, however the results remain variable and depend on many conditions and factors related to the patient. (5)

These therapies have been effective for decades, but they have notable limitations since they do not restore any biological function and do not allow the recovery of tissue vitality.

Thus, modern dentistry tends to go beyond simple mechanical repair to aim for a living and functional reconstruction of tissues, an approach embodied by regenerative dentistry. This is a

field that is booming and fully evolving and aims to restore the shape, biological function, and vitality of lost dental tissues. (6)

1.3. Emergence of regenerative dentistry

In the near future, dental caries and fractures may no longer require fillings or prosthetic replacements, as they could be naturally repaired by the body itself. This is the fundamental objective of regenerative dentistry. Regenerative dentistry is a new method that has revolutionized modern dentistry. It allows the body's natural ability to repair and reconstruct lost or damaged tooth tissue. It involves the neoformation of dental tissues such as dentin, enamel, dental pulp, periodontium, alveolar bone. This is an emerging field that explores biomimetic solutions to repair and regenerate damaged teeth. (4)

Traditional treatments focused only on tissue repair and restoration; recent studies have paved the way for a new regenerative approach. The role of this breakthrough is to rebuild a living tissue while maintaining all their capabilities and functions. We are no longer satisfied with simply filling a cavity or placing an implant or prosthesis, as the goal is now to restore lost biological functions that can be naturally repaired by the organism itself. Regenerative dentistry relies on the use of stem cells and biomaterials to restore them.

This approach in dentistry was made possible after the discovery and progress of regenerative medicine. Its use in odontology is based on three major elements which are stem cells, scaffolds and growth factors. These three components are indispensable in the neoformation of new biologically viable dental tissues.

Thus, thanks to the combination of these three, it is now possible to consider the regeneration of dental tissues. (3)

1.4. Stem cells in dentistry

Stem cells are defined as undifferentiated cells capable of self-renewal and differentiation into specialized cells. They constitute a reservoir of cells for growth, replacement, and repair of tissues in the body. (4)

Dental stem cells are a specialized type of stem cells found in different parts of the dental structure such as the dental pulp, dental follicle, periodontal ligament, and apical papilla.

These cells are capable of differentiating into multiple specialized cell types involved in dental tissue formation, such as odontoblasts and osteogenic cells, thereby contributing to tissue repair and regeneration. (7)

Regenerative dentistry is based on the use of stem cells to restore damaged oral tissues, providing new therapeutic possibilities for conditions that were once considered irreversible. In dentistry, research conducted since the 2000s has identified several sources of stem cells of dental origin grouped under the term dental stem cells (DSCs). (8)

Several populations of dental stem cells have been identified, each originating from specific dental tissues and presenting regenerative properties. The most commonly described types include dental pulp stem cells (DPSCs), stem cells from human exfoliated deciduous teeth (SHED), stem cells from the apical papilla (SCAP), periodontal ligament stem cells (PDLSCs), and dental follicle stem cells (DFSCs). (8)

SHED represent a readily accessible source of postnatal stem cells, which can be isolated and cultured *ex vivo*, but they can only be collected from children. (8)(9)

SCAP are mesenchymal cells that are located in the apical region of immature permanent teeth. The tissue called the apical papilla is distinct from the dental pulp. It contains fewer cells and vessels than the latter and is separated by an apical area rich in cells.

PDLSCs are stem cells that can be taken from the surface of extracted roots. (8)(9)

DFSC originate from the dental follicle, a tissue surrounding the developing tooth germ. These progenitor cells contribute to the formation of periodontal structures, including cementum, periodontal ligament, and alveolar bone.

Finally, DPSCs are derived from the pulp tissue, which contains nerve fibers and blood vessels, as well as several cell types, including fibroblasts and odontoblasts. These cells are capable of differentiating into odontoblast-like cells, particularly in response to injury, and play a major role in dentin regeneration. (9)(10)

These different cells belong to the family of mesenchymal stem cells (MSCs) and share common biological properties. MSCs have some advantages compared to cells from other tissues, such as those of bone marrow or adipose tissue, since they are easier to isolate from extracted teeth. Their collection is minimally invasive in the case of SHED and raises fewer ethical concerns. They are also very effective since there is a reduced risk of rejection. (9)

Stem cells therefore play an essential and central role in the neoformation of dental tissues since they provide the necessary cell base. Associated with scaffolds, which are three-dimensional biocompatible structures, they serve as a support allowing the adhesion and proliferation of these cells. Growth factors are also used to promote tissue formation since they allow the formation of specific structures. They play a key role in the physiological differentiation of odontoblasts, as well as in repair phenomena. Particularly TGF- β (transforming growth factors B) which may be directly involved in the differentiation of odontoblasts. (11)

The first experiments were conducted to regenerate the pulp. Research has shown that by stimulating the apical environment while adding cells, it is possible to reconstitute a vital, innervated, and vascularized pulp. This treatment is called regenerative endodontics. This research was conducted using DPSCs and SHED.

DPSCs were first studied in 2000 by Gronthos et al. and are derived from the pulp of extracted permanent teeth. These cells are located within the dental pulp and have demonstrated the ability to contribute to dentin formation as well as other tissue types. They can be obtained from extracted teeth, making them a readily accessible source. (12)

SHED, discovered by Miura et al. in 2003, have remarkable clinical accessibility thanks to their origin from naturally exfoliated deciduous teeth. (13)

Moreover, studies have also shown the effectiveness of using stem cells in the neoformation of the periodontal ligament and the alveolar bone by combining them with biomaterials.

PDLSCs and DFSCs are found to be highly effective in periodontal regeneration and are another promising source. They manage periodontal disease which affects millions of people. (14)

Stem cells are also being explored in the context of dental implantology. Implants are a major revolution in current odontology but rely on the quality and quantity of the alveolar bone. Thus, stem cells have the ability to regenerate bone to improve the success rate of implants. (14)

Studies have shown that stem cells could be used to grow whole teeth in the laboratory. Researchers used DPSCs to grow teeth in vitro. Although still at an experimental stage, this approach could represent a breakthrough for patients with tooth loss.

Enamel, the hardest tissue in the human body, does not naturally regenerate. However, recent studies have led to the development of biomaterials capable of promoting the remineralization of enamel and dentin. Calcium and phosphate nanoparticles are thus used to strengthen weakened teeth without resorting to traditional restoration techniques.

In the near future, dental stem cell therapies could revolutionize the way we approach dental care. These innovations promise to transform dental practice by offering solutions that not only improve the quality of care but are also more sustainable and less invasive. New methods of regenerating dental tissue could reduce costs in the long term for both patients and health systems. Stem cells offer promising prospects in regenerative dentistry, but several challenges still hinder their clinical application, including technical, biological, and economic limitations that require further research and clinical validation. (15) (16)

2. JUSTIFICATION:

Modern odontology is currently at a crossroads between traditional restorative dentistry and the innovation of regenerative dentistry. For a long time, dentistry has relied on replacement and restoration methods with the use of crowns, implants, prostheses, and endodontics. Even if all these treatments have allowed enormous progress in dentistry in recent years, they remain very limited since they do not restore the vitality of the tooth or dental tissues. They cannot indeed replace all the biological functions that a living organ can provide.

That is why in the 20th century, regenerative dentistry emerged after the discovery of regenerative medicine. By using stem cells, doctors began to be able to restore the life of organs instead of simply replacing what had been lost.

If stem cells represent one of the hopes of therapies for doctors, they are now also a hope for dentists. Recent progress in cell biology and tissue engineering has opened new possibilities for the regeneration of damaged dental tissues.

The subject of the use of stem cells in the neoformation of dental tissue is therefore relevant in relation to its current importance but also in relation to its scientific relevance. Tooth loss is a huge current problem that impacts the entire world and therefore remains a global and universal issue.

This advancement would represent a way forward to find a real treatment for cavities, traumas, and periodontal diseases. With this method, patients could today no longer need to wear prostheses, it would allow tissues to be repaired while restoring vitality, while offering better durability and less invasive treatments.

Moreover, this subject is totally in line with current developments, since advances in technology and science could allow the development of new biomaterials. Soon, it might be possible to create new scaffolds to fully regrow teeth.

Like all health professionals, the dental surgeon will therefore also soon be confronted with stem cells and regenerative medicine. Thus, the objective of this work is to study how stem cells could modify our future activity, through a model that seems most likely to be usable one day: dental pulp stem cells.

Dental practice is constantly evolving and tends more towards a conservative philosophy. This is why stem cells and their potential for regeneration are of great interest to researchers in the field of dentistry and make them a major current challenge. Stem cells are today at the center of scientific news and are the new hope for dentists.

Then, on the ethical level, this advance would be ideal since it allows for real respect for the human body. Indeed, the use of these cells would be better accepted, since they offer easier

and less invasive access and allow the avoidance of controversies about the use of embryonic cells.

This breakthrough would have a real impact on the dentist's practice; it would minimize the patient's pain and allow them not to have to use a device all their life and to regain healthy and vital teeth. Dental stem cells could completely change the quality of life for patients and people around the world.

To conclude, the use of stem cells is also a major advance since it is a rather conservative method. Implants, on the other hand, require a much more invasive surgical procedure than stem cells, as they involve bone drilling followed by the placement of the implant within the bone and may sometimes require bone grafts, whereas regenerative strategies aim to stimulate the patient's natural biological capacities. It would reduce the operative consequences as well as the risks of post-surgical complications.

Thus, this procedure would be less aggressive, less invasive, and would allow the maintenance of tissues. It would provide a physiological alternative, more durable and more biocompatible.

3. OBJECTIVES

Main objective:

- 1- To evaluate how stem cells could transform current dentistry into regenerative dentistry capable of reproducing living and functional dental tissues, and to identify the different types of stem cells involved.

Secondary objectives:

- 2- To describe the mechanisms and stages of dental tissue neoformation, including isolation, culture, differentiation, and their interaction with biomaterials and growth factors.
- 3- To assess the potential impact of stem cell therapies on patients' quality of life, as well as their advantages and current limitations in clinical practice.

4. MATERIAL AND METHODS

4.1. Type of study

This study focuses on the use of stem cells in the neoformation of dental tissue. It is a descriptive and analytical literature review based on the study of scientific articles that are already published. The objective of this study is to analyse and synthesize current knowledge regarding the application of stem cell therapies in regenerative dentistry.

This research is non-experimental, as it relies exclusively on the analysis of existing scientific literature. No in vitro or in vivo experimentation was carried out within the framework of this thesis.

4.2. Databases

To carry out this study, relevant scientific articles were identified and collected through internationally recognized medical and scientific databases, including PubMed and Medline Complete, found in the Centre Dulce Chacón Library of the European University of Madrid.

These databases were selected for their methodological quality as well as for their scope of publication in the medical field and in stem cell research applied to dentistry and dental regeneration.

4.3. Keywords and search strategy

A total of 16 scientific articles published within the last 10 years were selected in order to ensure the inclusion of recent and relevant data. One additional article from 2008 was included due to its significant contribution to the understanding of dental stem cells.

The search strategy was designed to cover all key aspects of the subject, focusing on the role of stem cells in dental tissue regeneration. Only studies containing primary data and directly related to the research topic were included.

The search was performed using a combination of keywords such as: Dentistry, Dental Stem Cells, Regenerative Dentistry, Dental Tissue Regeneration, Tissue Engineering, Biomaterials, Scaffolds.

To refine the search, these keywords were used individually or in combination with Boolean operators such as AND, OR, and NOT. For example: “dental stem cells” AND “dental tissue regeneration” AND “regenerative dentistry” AND “tissue engineering”.

This approach allowed the identification and selection of scientific publications specifically addressing the role of stem cells in the regeneration of dental tissues.

4.4. PICO question

Recent advances in regenerative dentistry have highlighted stem cell-based therapies as a promising strategy for dental tissue regeneration. Therefore, it is important to evaluate whether these innovative treatments provide better clinical outcomes compared to conventional therapies.

The research question was structured according to the PICO model:

PICO ELEMENT	DESCRIPTION
P (POPULATION)	Patients with dental tissue damage or tooth loss
I (INTERVENTION)	Stem cell-based regenerative therapy
C (COMPARAISON)	Conventional dental treatments
O (OUTCOME)	Regeneration of dental tissues

Table 1. PICO framework used to structure the research question on stem cell-based dental tissue regeneration

Based on this framework, the following research question was formulated: *In patients with dental tissue damage or tooth loss (P), how does stem cell-based therapy (I), compared to conventional dental treatments (C), affect dental tissue regeneration and clinical outcomes (O)?*

4.5. Inclusion and exclusion criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
Articles published between 2008 and 2025	Articles published before 2008
Articles in English	Articles in other languages
Studies related to stem cells	Studies not related to the dental field
Articles focusing on dental pulp, periodontal and bone regeneration	Studies not related to tissue regeneration
Scientific articles related to the use of stem cells in dental tissue regeneration	Articles not related to dental tissue regeneration
Studies investigating dental stem cells (DPSCs, SHED, SCAP, PDLSCs.)	Studies not involving stem cells
Articles describing techniques of stem cells in the application in dentistry	Articles not describing regenerative or biological mechanisms
Publications available in full text	Articles not available in full text
Experimental studies (in vitro, in vivo, clinical studies)	Blogs, opinion papers, non-academic sources, non-scientific publications
Studies related to regenerative medicine	Studies on embryonic cells unrelated to dentistry

Table 2. Inclusion and exclusion criteria

4.6. Selection process

The selection process of articles was carried out in a structured and systematic manner. The articles were first selected from databases according to the search strategy described previously. A first selection process was carried out based on the screening of article titles.

Then, the abstracts were reviewed to verify that the articles were related to the selected topic on the use of stem cells in dentistry.

This step was intended to exclude publications that were clearly not relevant under the previously defined eligibility criteria. Notably, out-of-scope articles, literature reviews, and studies not related to dental stem cells or tissue regeneration were excluded.

Following these steps, the selected articles were analysed in full text. This in-depth reading made it possible to gather relevant information on the neoformation of dental tissues using stem cells. The following elements were systematically identified: year of publication, author, country, origin of stem cells (dental pulp, deciduous teeth, apical papilla, periodontal ligament), type of stem cells used (DPSCs, SHED, SCAP, PDLSCs, etc.), experimental conditions, type of regenerated tissue (pulp, dentin, periodontal ligament, alveolar bone), use of biomaterials or scaffolds, growth factors involved, results obtained, advantages, identified limits, and clinical perspectives.

The extracted data were then organized into three comparative tables, allowing a clearer and more structured synthesis of the collected information.

This organization made it possible to identify the similarities and differences between the studies. The data were presented in comparative tables to facilitate reading, synthesis, and interpretation of results.

These tables enabled a descriptive analysis of the results, highlighting the most studied applications and stem cell types.

Based on these findings, a discussion was developed to compare the results of the different studies and assess their consistency.

4.7. PRISMA Flow diagram

This literature review was carried out using the PubMed and Medline Complete databases to identify studies focusing on stem cell applications in dental tissue regeneration. The search process allowed the identification of a total of 435 records. After the removal of duplicates, the remaining studies were screened based on their titles and abstracts in accordance with previously defined eligibility criteria. The full texts of the selected articles were examined to determine their relevance. In total, 17 studies were finally included in this review. The selection process is illustrated in the PRISMA 2020 flow diagram presented below.

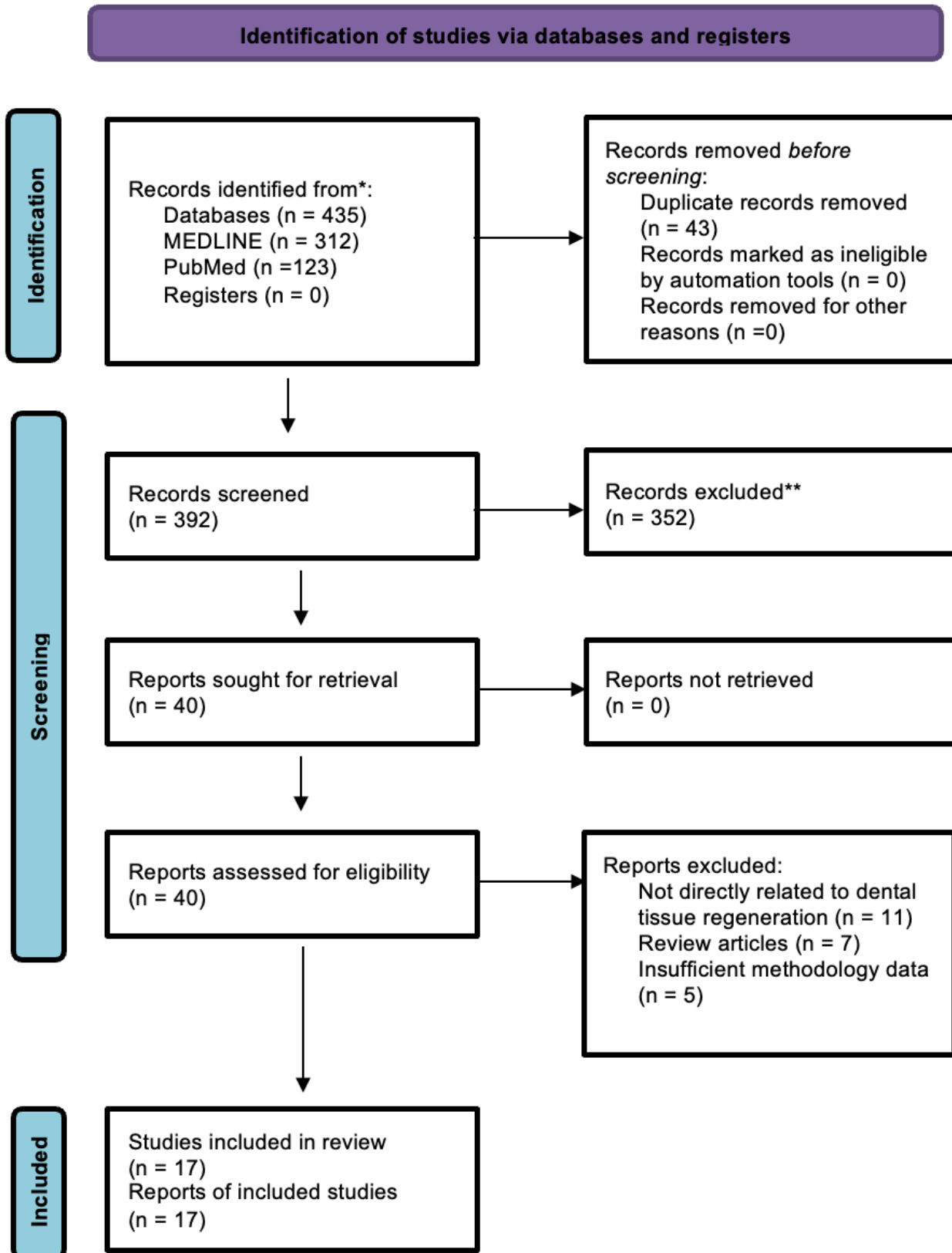


Diagram 1. Prisma flowchart with data extraction

5. RESULTS

5.1. Types of dental stem cells and their role in advancing regenerative dentistry

To understand how regenerative dentistry can transform modern dentistry and to identify the different types of stem cells used, five relevant articles were selected and analysed.

The study by Bluteau et al. (2008) is a major reference in this field, demonstrating that stem cells have strong potential in dental tissue regeneration and can be used to reproduce biological functions.

The article also identifies different sources of stem cells involved in these processes, including both mesenchymal and epithelial stem cells, which are necessary to reproduce complete tooth structures.

The article identifies different sources of stem cells involved in these processes, including mesenchymal stem cells from the dental pulp, periodontal ligament or deciduous teeth. These cells have a strong capacity for self-renewal and differentiation, allowing them to contribute to the regeneration of dental and periodontal tissues. In addition, the study shows that these cells can be used in vitro and in vivo to regenerate structures and thus maintain natural functions.

Finally, the study highlights that this therapy is a promising alternative to conventional treatments, although some limitations remain. (10)

Furthermore, the study by Bansal and Jain (2015) provides a clear summary of the different types of stem cells involved in these processes. They identify dental pulp stem cells (DPSCs), stem cells from exfoliated deciduous teeth (SHED), stem cells from the apical papilla (SCAP) and periodontal ligament stem cells (PDLSCs). These different cell populations have a significant capacity for self-renewal and differentiation, allowing them to participate in the regeneration of various dental tissues, such as dentin, pulp or periodontal structures.

DPSCs, for example, can form dentin and a dentin-pulp complex, while SHED show a higher proliferative capacity and extended differentiation potential. SCAP play an important role in the formation of root dentin, and PDLSCs contribute to periodontal tissue regeneration. These properties explain their importance in regenerative dentistry, as they can contribute to the repair of different dental tissues. (17)

Finally, three other articles were also analysed, and their results were summarized in a comparative table to allow a clear and structured comparison of the data.

Author, Year and country	Study Type	Stem cells used	Source	Key biological properties	Main findings
Patel MJ et al (2025), India	Cross-sectional study	DPSCs, SHED, PDLSCs, SCAPs, MSCs	Dental pulp, exfoliated deciduous teeth, periodontal ligament, apical papilla	MSC populations (PDLSCs, SCAP, DFSCs) show greater regenerative potential than DPSCs High proliferative and differentiation capacity Limited knowledge among dental professionals	Awareness of stem cells exists among dental professionals Regenerative dentistry is perceived as promising Knowledge and clinical application remain limited
Pawar et al. (2024), India (18)	Literature review	SHED	Exfoliated deciduous teeth	High proliferative capacity Strong osteogenic differentiation potential	SHED exhibit higher regeneration potential compared to DPSCs SHED can differentiate into osteogenic cells when combined with PRP When combined with β -TCP, SHED promote bone regeneration
Anitha K. et al. (2024), India (19)	Cross-sectional study	DPSCs, SHED, PDLSCs, SCAPs, DFSCs	Dental pulp, exfoliated deciduous teeth, periodontal ligament, apical papilla, dental follicle	Multipotent differentiation capacity High regenerative potential of dental stem cells	93.2% of participants were aware of stem cells, but only 30.2% had knowledge of clinical applications. Knowledge was higher among dentists with more than 10 years of experience Lack of knowledge regarding stem cell collection methods. SHED showed higher differentiation potential

Table 3. Types of dental stem cells, their biological properties, and their role in regenerative dentistry

5.2. Mechanisms and stages of dental tissue neoformation from stem cells, including their interaction with biomaterials and growth factors

To analyse the mechanisms and stages involved in the regeneration of dental tissue using dental stem cells, seven relevant articles were selected and analysed.

The study by Leyendecker Júnior et al. (2018) highlights the major role of SHED and DPSCs in the neoformation of dental tissues. The authors describe a process starting with the isolation of these cells from dental pulp, followed by their culture and in vitro expansion, prior to their use in tissue engineering. These cells have a strong capacity for dental regeneration. The article emphasizes that their association with biomaterials is essential for regeneration. Several types of scaffolds are described, including biodegradable polymers such as PLGA, ceramics such as hydroxyapatite and β -tricalcium phosphate, as well as composite materials combining these different properties. These biomaterials play an essential role by providing a three-dimensional structure allowing the adhesion, migration, proliferation, and differentiation of cells, while promoting the vascularization necessary for the formation of functional tissue. The results show that the association between stem cells and scaffolds allows efficient bone formation in vivo. (20)

The study by Wu P.H. et al. (2025) highlights the essential role of growth factors, particularly in the formation of the pulp-dentine complex. Among the factors studied, the basic fibroblast growth factor (bFGF) appears as a key element. They show that bFGF promotes cell proliferation, migration and differentiation, and plays a crucial role in revascularization. The study also highlights the role of other growth factors involved in regeneration, such as VEGF, PDGF and TGF- β , which are involved in cell recruitment and the modulation of differentiation. (21)

Finally, the study by Saberian E. et al. (2024) shows the importance of scaffolds in bone and dental tissue regeneration. This paper describes different scaffolds, including PLGA/HA, chitosan and calcium phosphate, and demonstrate and that these biomaterials allow the adhesion, migration, proliferation and differentiation of stem cells, while promoting vascularization and nutrient exchanges necessary for the formation of a functional tissue. The study reports that combining scaffolds with SHED enhances bone regeneration, although its clinical application remains limited. (11)

In addition, four other articles were analysed and are presented in a summarized form in the comparative table below.

Author, Year and country	Study Type	Stem cells	Biomaterial / Growth factor	Regenerated tissue	Main findings
Wang et al. (2025), China (22)	In vitro experimental study	DPSCs	Sodium Hypochlorite (NaOCl)	Dental pulp	Low concentrations of NaOCl preserves cell viability High concentrations induce damage and reduce osteogenic differentiation
Yuan et al. (2026), China (23)	In vitro experimental study	SCAP-derived exosomes, DPSCs	Exosomes	Pulp and dentin regeneration	SCAP-derived exosomes isolated under hypoxic conditions Enhanced migration and odontogenic differentiation of DPSCs
Taymour et al. (2026), Korea, Egypt, UAE, Saudi Arabia (24)	Narrative review	DPSCs, PDLSCs, SHEDs, SCAPs, DFSCs, GMSCs,	Hydrogels, Chitosan, Alginate, Collagen, PLGA, hydroxyapatite (HA)	Periodontal tissue	Hydrogels promote periodontal tissue regeneration Limited clinical evidence available
Alauti et al. (2025), Saudi Arabia (25)	Experimental study	PDLSCs	Melatonin	Alveolar bone and periodontal tissues	Melatonin enhances cell viability Promotes osteogenic differentiation of PDLSCs

Table 4. Mechanisms and stages of dental tissue neoformation

5.3. Clinical applications and impact of stem cell–based therapies in regenerative dentistry

To analyse the clinical applications of stem cell therapies in regenerative dentistry, as well as their impact, benefits, and limitations, two relevant articles were selected and analysed.

The study by Dipalma et al. (2025) highlights the potential for regeneration, particularly in periodontal tissue, alveolar bone, and dental pulp. The results show an improvement in clinical outcomes, including bone formation, periodontal healing and pulp regeneration, thus confirming the ability of mesenchymal stem cells (MSCs) to regenerate soft and hard tissues. Also highlighted are the advantages of this therapy, including its minimally invasive nature and the use of autologous cells that reduce the risk of immune rejection and improve biocompatibility.

This article also indicates that these therapies could improve patients' quality of life by reducing the need for invasive procedures and repeated treatments. However, the article also highlights several limitations such as short follow-up periods and small sample sizes. These limitations result in a lack of solid evidence in the long term and limit their current clinical application. (26) The study by Yamada et al. (2020) confirms these results by showing that most clinical trials report benefits, particularly in bone, periodontal, and pulp regeneration. This study also shows the absence of major adverse effects, suggesting a good safety of these therapies. These results indicate a positive impact on patients' quality of life.

However, some limitations remain, including the lack of standardized clinical protocols, variability in treatment approaches, and insufficient long-term follow-up data. These factors limit the ability to fully assess the long-term effectiveness and predictability of these therapies.(27)

In addition, three other articles were analysed and are presented in a summarized form in a comparative table below, allowing a clearer visualization of clinical applications, benefits, and limitations.

<i>Author, Year, country</i>	<i>Study Type</i>	<i>Clinical application</i>	<i>Clinical outcomes</i>	<i>Clinical advantages</i>	<i>Limitations</i>
Umapathy V.R et al. (2025), India / UAE (6)	Narrative review	General regenerative dental therapies (pulp, dentin, periodontium)	Promising regenerative outcomes in preclinical and early clinical studies	Ability to restore living tissues instead of replacing them, Improved patient outcomes	High cost Regulatory constraints Challenges in vascularization and integration
Karadede B. (2025), Turkey (28)	Narrative review	Applications in regenerative dentistry	Increasing evidence supporting stem cell-based therapies	Promotes dentin and bone regeneration Enhances tissue healing Potential alternative to dental implants Reduces immune rejection	Ethical concerns Technical complexity High cost Limited accessibility
Shirmohammadi et al., 2023 (29)	Editorial perspective	/ Whole tooth regeneration (bioengineered tooth)	Experimental success in forming tooth-like structures	Potential alternative to dental implants Fully biological restoration	Still at an experimental stage Lack of clinical application in humans

Table 5. Clinical applications, outcomes, advantages and limitations of stem cell–based therapies in regenerative dentistry

6. DISCUSSION

Current dentistry is evolving towards a regenerative approach rather than a restorative one. Indeed, conventional dental treatments do not allow the reproduction of the biological functions of damaged organs and living tissues. In this context, stem cells have been increasingly studied, opening the way for new therapeutic strategies aimed at regenerating dental tissues instead of simply replacing them.

To answer our research question, several articles were selected from databases to analyse all the different types of stem cells used in dentistry, the mechanisms involved in tissue neoformation, and finally the future perspectives and the limitations.

6.1. Identification of all stem cells used in dentistry

The analysis of the selected articles highlights the main stem cells used in dentistry. These studies show that the oral cavity is a rich source of stem cells capable of regenerating dental tissues.

According to Patel et al. (2025), several types of stem cells can be isolated from dental tissues, including DPSCs, SHED, PDLSCs, SCAPs and DFSCs. These cells mainly belong to the mesenchymal stem cells (MSC) family, which are the most studied category of cells in regenerative dentistry. These cells have a self-renewal capacity and can also form into different types of cells such as osteoblasts, adipocytes and chondrocytes. They have a strong regenerative potential allowing the formation of different types of cells involved in the structure of the tooth and supporting tissues.

These results are confirmed by the studies of Anitha et al. (2024) and Patel et al. (2025), which show that there are several types of stem cells with different properties. For example, SHED and SCAP have a higher proliferation capacity than DPSCs, which means that the choice of cells must be adapted to the type of regeneration sought.

6.1.1. DPSCs: Stem cells of the dental Pulp

Dental Pulp Stem Cells (DPSCs) are among the most studied and are usually obtained from human dental pulp, most often from impacted third molars or extracted permanent teeth. They possess a high capacity for regeneration.

Studies show that these cells can differentiate into odontoblasts and thus allow the creation of dentin. According to Bansal et al. (2015), DPSCs play a key role in the regeneration of the dentin–pulp complex.

Studies also show that DPSCs can regenerate bone and periapical tissues due to their osteogenic, adipogenic, and chondrogenic potential. When combined with biomaterials or 3D scaffolds, they can recreate structures like natural dental tissues.

However, Patel et al. (2025) suggest that although DPSCs are widely used, other stem cells such as SHED or PDLSCs may have higher proliferative capacity in some conditions.

6.1.2.SHED: stem cells from exfoliated temporary teeth

SHED represent a very promising source of stem cells. One of their main advantages is that they are obtained from naturally exfoliated teeth, which makes their collection non-invasive and easily accessible.

These cells have also been subject to many recent studies in the field of dental regeneration. According to Pawar et al. (2024), SHED have a higher proliferation rate and a strong differentiation capacity, especially in osteogenic pathways. This makes them particularly effective for bone regeneration.

Their interaction with biomaterials or biological factors such as platelet-rich plasma (PRP) is also well studied and shows their interest. (Pawar et al. 2024).

Bansal et al. (2015) also highlight that SHED have multi-lineage differentiation ability, which makes them useful for different regenerative applications.

6.1.3.SCAP: apical papilla stem cells

SCAPs are obtained from the apical papillae of developing teeth. They are an important source of stem cells. They can be taken from the end of the dental roots during tooth maturation, which explains their strong proliferative capacity.

According to the studies, these cells therefore have a strong regenerative capacity, particularly in the regeneration of radicular dentine and for their central role in endodontic regeneration therapy of immature teeth with pulp necrosis.

Studies show that SCAPs have a proliferation capacity that is higher than DPSCs.

Moreover, the article that discusses studies on SCAP exosomes in hypoxia allows for greater precision: they are not only grafts; they can also modulate other dental cells via their exosomes.

6.1.4.PDLSCs: periodontal ligament stem cells

PDLSCs are isolated from the periodontal ligament, particularly on the surface of the roots of the teeth that have been extracted.

These cells have an important regenerative capacity and according to Bansal et al. (2015) these cells are especially involved in the regeneration of periodontal tissues such as periodontal ligament, alveolar bone, and cementum. The articles highlight that these are the most used cells in the treatment of periodontal diseases.

Several studies were conducted on animals to reconstruct the bone/cementum/periodontal ligament structures and in some articles, it appears that trials were carried out on humans to regenerate periodontal tissues.

Patel et al. (2025) also suggest that PDLSCs have a strong proliferative capacity and may perform better than DPSCs in some regenerative conditions.

6.1.5.DFSCs, TGPCs, TGSCs: cells of developing dental tissues

Dental follicle stem cells (DFSCs) are cells that come from the dental follicle. They are very useful for the regeneration of the periodontium (cementum, alveolar bone and periodontal ligament) because the follicle is embryologically linked to the formation of periodontal tissues.

Anitha et al. (2024) also include DFSCs among the main stem cells used in dentistry, highlighting their multipotent differentiation capacity.

Finally, the last type of cells studied in regeneration are the tooth germ progenitor (TGPCs or TGSCs), which are cells located in the dental germ. They have a major interest because they not only allow to regenerate a tissue but potentially to recreate a complete dental unit. Indeed, in the presence of a suitable 3D scaffold and certain signals they could participate in the formation of a complete tooth with all tissues, crown, root, pulp, ligament and bone. However, these approaches remain experimental and require further research.

6.2. Mechanisms of dental tissue neoformation from stem cells

The neoformation of dental tissues is based on a succession of closely related steps. Stem cells alone are not sufficient for tissue regeneration, it must be accompanied by appropriate conditions, including isolation, culture, and the presence of biomaterials or scaffolds.

The selected studies show that regeneration depends on the interaction between stem cells, signalling molecules, and the surrounding environment.

The study by Leyendecker Junior et al. (2018) shows that regeneration relies on the interaction between stem cells, biomaterials (scaffolds), and signalling molecules, and that their good coordination is essential to achieve an effective result.

6.2.1. Selection of cells

The first step is the selection of stem cells. In regenerative dentistry, we have seen that there are different types of stem cells used for neoformation such as SCAP, SHED, DFSCs, PDLSCs, DPSCs. We collect DPSCs from the dental pulp, SHED from exfoliated deciduous teeth, SCAP from the apical papilla of immature teeth, PDLSCs from the periodontal ligament, and finally TGPCs from the dental germ.

The choice of cells directly depends on the tissue that one wishes to regenerate. If we want to reconstruct a pulp-dentine complex, the DPSCs and SHED are used. For root regeneration, we will use the SCAP. For periodontal tissues, the PDLSCs and DFSCs are the most specific. (20)

6.2.2. Cell isolation, culture and differentiation

After selection, stem cells must be isolated, usually from extracted or naturally exfoliated tooth, using enzymes to dissociate the tissues.

Once isolated, the cells must be cultured. This means that they are grown in a laboratory in an appropriate nutrient medium. The aim is to multiply them to have enough cells to use. They are cultured in controlled conditions to allow their expansion. Cell culture is a key step, where stem cells are directed toward specific cell types such as odontoblasts, osteoblasts, or periodontal cells.

In regenerative dentistry, we mainly seek to orient the cells towards odontoblasts to form dentin, osteoblasts to form bone. Cells from the periodontal ligament or cementum, to regenerate the periodontium. For this, the cells are placed in particular conditions, with specific culture media and sometimes molecules that stimulate their transformation. (20)

The differentiation process is highly dependent on the presence of specific growth factors such as bFGF, VEGF, and TGF- β , which regulate cell proliferation, migration, and lineage commitment, as demonstrated by Wu et al. (2025).

6.3. Scaffolds, biomaterials and growth factors in regenerative dentistry

In regenerative dentistry, stem cells cannot act on their own: they need a supportive environment to survive and differentiate. This is why scaffolds, biomaterials, and growth factors play such an important role in dental tissue regeneration. A scaffold is a three-dimensional support that allows the cells to attach. It must be biocompatible, so it allows the recreation of an environment favourable to regeneration.

The study by Saberian et al. (2024) highlights that the use of scaffolds such as PLGA/HA, chitosan, or calcium phosphate, in combination with dental stem cells such as DPSCs, PDLSCs, or GMSCs, can enhance alveolar bone regeneration. It also clearly demonstrates that the combination of SHEDs and biomaterials facilitates alveolar bone regeneration, although further research is still needed.

Saberian et al. (2024) showed that the association of SHED with scaffolds significantly improves bone regeneration in vivo. However, these methods are still limited in clinical practice by the lack of long-term experience.

Furthermore, the study by Leyendecker Junior et al. (2018), which analyses in vivo the combination of dental stem cells such as DPSCs and SHEDs with various scaffolds such as collagen, HA/TCP, β -TCP, or PLGA, reinforces the idea that this combination has strong potential for bone regeneration. This article confirms that this combination is a key element in dental regeneration. Similarly, Leyendecker Junior et al. (2018) confirmed that scaffold composition plays a key role in directing cell differentiation and tissue organization, particularly when combining natural and synthetic biomaterials.

6.3.1. Natural scaffolds

Collagen is one of the most used biomaterials because it is a protein that is naturally present in many tissues and resembles the natural matrix of pulp and dentine. The studied articles show that DPSCs and SHED seeded in collagen matrices can easily proliferate to form vessels and participate in the formation of a dentin and pulp tissue (Leyendecker Junior et al., 2018; Saberian et al., 2024).

Fibrin in the form of PRF or PRP also plays a major role in the formation of vessels. It is rich in growth factors and promotes healing and angiogenesis (Wu et al., 2025).

Chitosan is a biocompatible biomaterial and is favourable to wound healing. Used alone or in composite with collagen or hydroxyapatite, it improves the proliferation of DPSCs. (Saberian et al., 2024).

Hyaluronic acid participates in the hydration and organization of the extracellular matrix. It can be used as a hydrogel, but its rapid degradation constitutes a limit (Taymour et al., 2026).

Alginate is useful for cell encapsulation; however, it poorly promotes cell adhesion. It is therefore often considered insufficient if used alone to recreate a fully functional pulp tissue (Taymour et al., 2026).

6.3.2.Synthetic scaffolds and hydrogels

The most used synthetic scaffolds are PLA (polylactic acid), PGA (polyglycolic acid), and PLGA (polylactic-co-glycolic acid). These materials are very interesting because they allow better control of the shape, their resistance and their degradation rate. They are widely used in pulp tissue engineering and bone regeneration. (Leyendecker Junior et al., 2018; Saberian et al., 2024).

In addition, among biomaterials, hydrogels are used. Hydrogels are very water-rich materials and constitute a very important category of biomaterials. Indeed, their main interest is to allow a homogeneous distribution of cells in a three-dimensional space.

The study by Taymour et al. (2026) shows that combining hydrogels with dental stem cells may enable the regeneration of periodontal tissues. However, it is noted that further studies and research are still needed.

Growth factors are also used in regeneration by stimulating the proliferation, migration, and differentiation of stem cells. In the article by Wu et al. (2025), bFGF is used because its combination with DPSCs and SCAPs promotes the regeneration of the pulp-dentin complex.

In addition to growth factors, there are other mechanisms of cellular communication. Some studies also show that stem cells can interact with one another. For example, SCAP-derived exosomes can stimulate DPSCs and enhance their differentiation and migration (Yuan et al., 2026).

6.3.3.Influence of microenvironment

The study by Alauti et al. (2025) highlighted how melatonin may also play an important role in tooth regeneration. This study on melatonin is very important because it demonstrates how, at a certain concentration, it can improve cell viability and enhance osteogenic differentiation. Thanks to these very recent studies we can now understand that these cells do not only depend on themselves but also on the environment around them, which has an impact on periodontal regeneration.

Finally, the study by Wang et al. (2025) explains that the clinical environment plays an important role in stem cell-based regeneration. For example, here they discuss sodium hypochlorite (NaOCl) used in endodontics and note that low concentrations help preserve viability, while high concentrations reduce proliferation. This highlights the importance of adapting clinical protocols to preserve their regenerative potential.

These findings highlight that stem cells do not act alone and that the success of dental regeneration also depends on the biological environment and clinical conditions.

6.4. Future impact of stem cell use in dental tissue regeneration

6.4.1. A new approach

In recent decades, dentists have become interested in the potential of dental stem cells in regenerating dental tissue. These advances have opened new prospects for restoring not only the structure but also the biological functionality of the tissue.

According to the study by Umapathy et al. (2025), this new technique would make it possible to restore living tissue rather than simply replacing it. This would represent a breakthrough in dentistry and could significantly improve patients' quality of life.

It would also be one of the most promising approaches to addressing the limitations of conventional dental treatments. These advances could change the lives of many patients. According to Umapathy et al. (2025), regenerative therapies could move dentistry towards a more biological approach, which aims not only at repairing, but also at restoring the proper functioning of tissues.

6.4.2. The Benefits of Dental Regeneration

As mentioned above, regenerative therapy based on stem cells could replace lost or damaged tissue rather than simply replacing it with fillings, crowns, or implants. It aims to stimulate vascularization and restore tissue vitality, thereby improving its longevity.

These treatments would therefore be less invasive than current ones and would result in less post-operative pain and fewer interventions.

Dipalma et al. (2025) explain that the use of stem cells could improve clinical outcomes and, consequently, bone formation as well as periodontal and pulp regeneration. Thanks to these advances, the treatment of chronic periodontal diseases could be improved. Periodontal diseases are the main cause of tooth loss, and the use of stem cells from the periodontal ligament, pulp, or apical papilla could be beneficial for the regeneration of periodontal tissues.

Furthermore, Yamada's (2020) article explains that most studies show benefits without adverse effects, which reinforces the safety of using stem cells.

Finally, Karadede's article (2025) shows that these therapies may play a major role in bone and dentin regeneration and could thus improve healing when used in conjunction with implants.

If clinical applications become possible, these cells could restore supporting structures and thus the natural preservation of teeth.

6.4.3.Future prospects

It has been demonstrated that, in the longer term, it could be possible to recreate complete dental structures by combining mesenchymal stem cells and epithelial cells, which would produce dental germs.

This is explained in the article by Shirmohammadi et al. (2023), which highlights the potential of stem cells to enable the complete formation of the tooth may become a future alternative to dental implants.

Although these approaches are currently limited to experimental models, they open the prospect of one day being able to regenerate complete teeth. Such an advance would represent a complete revolution in modern dentistry.

6.4.4.Limitations and challenges encountered

Despite these major advances, numerous scientific, technical, and clinical obstacles must be overcome before this method becomes commonplace. One of the main challenges is understanding the mechanisms involved in this therapy.

This practice therefore requires precise coordination between different cell types, specific molecular signals, and an appropriate microenvironment. Controlling these interactions remains difficult to reproduce reliably in a clinical setting. Although many biomaterials and scaffolds have been studied, further research is still required to optimize their use. Dipalma et al. (2025) highlight numerous limitations, such as small sample sizes and short follow-up periods. As for the study by Yamada et al. (2020), it points to the limited number of studies and clinical trials, which is a major obstacle to clinical application.

In addition, the economic aspect represents a limitation. This technique requires special infrastructure, which comes at a cost. These financial constraints still greatly limit access to this practice. Umapathy et al. (2025) also emphasize the high costs associated with these therapies.

Finally, there is the question of ethics (Karadede, 2025). Although dental stem cells do not raise the same controversies as embryonic stem cells, their use still requires a regulatory framework. Several studies have also shown that many dentists still have limited knowledge about this method of regeneration. This can be explained by the fact that this practice is very recent and is mainly used in research rather than in clinical applications. It is therefore important to train dentists on this subject and to reinforce knowledge, particularly in university programs. So, limited knowledge among clinicians may also represent a barrier to clinical application.

In this context, although the therapies are still at the experimental stage, further research remains essential to improve this technique and bring about a real revolution in the field of modern dentistry. This new technique could completely transform patient care. To one day be able to use it on patients, significant scientific research efforts remain essential.

7. CONCLUSIONS

1. The results of this literature review highlighted that stem cells represent a major and very promising advance in the field of dental tissue regeneration. Overall, the analysis made it possible to evaluate their capacity to transform current dentistry into a regenerative approach capable of producing functional dental tissues.

Analysis of the selected articles revealed that dental pulp stem cells (DPSCs), stem cells from exfoliated deciduous teeth (SHEDs), stem cells from the apical papilla (SCAPs), and periodontal ligament stem cells (PDLSCs) have been the most studied cell types in this field. These cells have been the focus of research because they have a strong capacity for proliferation and differentiation, enabling them to regenerate dentin, pulp, cementum, alveolar bone, or periodontal tissues. These findings confirm that several stem cell populations play a key role in the development of regenerative dentistry.

2. The selected articles showed that regeneration relies on a combination of stem cells, biomaterials, and growth factors. The analysis also allowed the identification and evaluation of the main mechanisms involved in dental tissue neoformation, including stem cell isolation, culture, differentiation, and their interaction with the surrounding microenvironment.

The use of three-dimensional scaffolds, such as hydrogels, collagen matrices, or biodegradable polymers, creates a microenvironment conducive to cell proliferation and differentiation. These biomaterials play an essential role in the spatial organization of cells and in the formation of regenerated tissue. Growth factors further enhance these processes by regulating cellular behaviour and promoting tissue organization.

3. Finally, the use of stem cells in dentistry represents a major evolution in the field and is expected to transform patient care. This approach could restore tissue vitality, enable less invasive treatments, and improve the long-term preservation of teeth. The analysis of studies also highlighted the positive impact on patients' quality of life. It was highlighted that this advance would represent an evolution in dentistry and would transform patient care. This strategy could restore tissue vitality, thereby enable less invasive treatments and improving the longevity of teeth.

However, several limitations persist, notably the lack of long-term studies, high costs and technical challenges. Further research is needed before these advances can be implemented in clinical practice.

8. SUSTAINABILITY

The concept of sustainability now plays a central role in dentistry. In this context, the use of stem cells in regenerative dentistry appears to be a promising approach.

This method would represent an environmental advantage, since conventional treatments often rely on synthetic materials whose production and transportation have an environmental impact. The regeneration of dental tissue could reduce the use of biomaterials and promote more natural solutions.

From an economic standpoint, this development could reduce dental care costs over the long term, despite the current high costs associated with research and technology. Dental regeneration may help limit the need for repeated treatments or prosthetic replacements.

Furthermore, dental regeneration represents a major patient-centered advancement. The use of the patient's own stem cells reduces the risk of rejection and improves biocompatibility. These less invasive treatments could improve patients' quality of life.

However, many challenges remain. Numerous clinical trials and research studies are still needed before this method can be widely applied. Ethical considerations must also be considered.

Thus, although regenerative dentistry holds great promise in terms of sustainability, its widespread adoption will depend on future scientific, economic, and regulatory advancements.

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10.ANNEXES

Table 1. *PICO framework used to define the research question regarding the tissue regeneration with stem cells*

Table 2. *Inclusion and exclusion criteria*

Diagram 1. *Prisma flowchart with data extraction*

Table 3. *Types of dental stem cells, their biological properties, and their role in advancing regenerative dentistry*

Table 4. *Mechanisms and stages of dental tissue neoformation*

Table 5. *Clinical applications, benefits, and limitations of stem cell-based therapies in regenerative dentistry*