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Stem Cell Usage in Dentistry: A Promising Future

Berşan Karadede *
Assistant Professor, Department of Plastic and Reconstructive Surgery, Yalova University, Turkey

***Corresponding author:** Berşan Karadede, Assistant Professor, Department of Plastic and Reconstructive Surgery, Yalova University, Turkey.

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Abstract

Introduction: Stem cells are characterized by their ability to both regenerate themselves and develop into specialized cell types. They have the unique ability to self-renew and generate various cell types, offering innovative approaches for tissue regeneration and disease treatment. In dentistry, mesenchymal stem/stromal cells (MSCs) have been discovered in numerous oral and maxillofacial tissues, highlighting oral tissues as a plentiful reservoir of stem cells. These oral stem and mucosal cells are anticipated to serve as an excellent source for creating genetically reprogrammed cells, such as induced pluripotent stem (iPS) cells. Additionally, oral tissues are expected to function not only as a source but also as therapeutic targets for stem cell applications, as regenerative and tissue engineering therapies in dentistry gain growing clinical attention.

General Information: Stem cells can be derived from various sources, including dental pulp, periodontal ligament, and even oral mucosa. Dental stem cells are especially attractive due to their proximity to the oral cavity and their ability to differentiate into a variety of tissue types such as dentin, bone, and nerve cells. The concept of regenerative dentistry is to use stem cells to regenerate or replace damaged oral tissues, offering patients a solution to conditions that were previously considered irreversible. While stem cell therapy in dentistry is still largely experimental, the ongoing advancements in the field are promising.

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Clinical trials are underway to assess the safety and efficacy of stem cell-based treatments for various dental conditions. These trials will provide valuable data on how stem cells can be used to treat conditions such as tooth loss, periodontal disease, and TMJ disorders.

In the near future, stem cell-based treatments could become an integral part of dental care, offering patients a more natural and effective solution to dental problems.

Conclusion: In conclusion, stem cells hold great promise in the field of dentistry, offering a new frontier in regenerative treatments. Although there are challenges to overcome, the future of dentistry could see significant improvements in patient care, with stem cells playing a key role in repairing and regenerating oral tissues. As research continues to progress, stem cells may ultimately become a cornerstone of dental treatments, revolutionizing the way we approach dental care.

Keywords
Orthodontics; Stemcell; Dentistry

Introduction
Stem cells are defined by their capacity to replenish and transform into distinct specialized cell types [1, 2,3]. Stem cells offer a valuable avenue for exploring the processes that govern embryonic development, cell specialization, and organ upkeep. With their remarkable abilities to multiply and transform into various cell types, they hold immense promise for pioneering innovative cell-based treatments [4, 5]. Moreover, recent research indicates that disruptions in stem cell functions could be responsible for the development of certain cancers [6,7].

The concept of stem cells can be traced back to 1868 when the renowned German biologist Ernst Haeckel introduced the term in his scientific writings. Haeckel, a prominent advocate of Darwin's theory of evolution, created several phylogenetic trees to illustrate the evolutionary relationships among organisms, tracing their descent from shared ancestors. He described these trees using the term "Stammbäume" (a German word meaning family or stem trees). In this scenario, Haeckel coined the term "Stammzelle" (a German word meaning stem cell) to refer to the single-celled organism he considered the ancestor of all multicellular life forms [8, 9]. The word "stem cell" began to be used later in the 19th century to describe a specific embryonic cell able of developing into more specialized cell types (Figure 1).

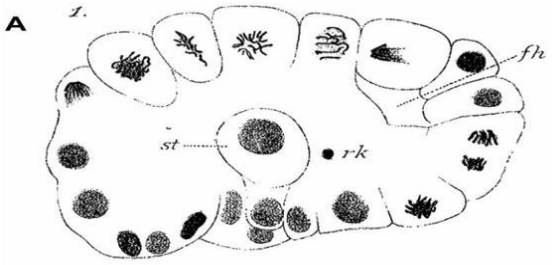

Figure 1: Historical Context of the Term 'Stem Cell'

A. Valentin Häcker's 1892 illustration depicting the stem cell in a Cyclops embryo. Häcker described

the stem cell (st) as having recently moved into the embryo's interior and being on the verge of undergoing asymmetric division. This division results in one daughter cell forming the germline, while the other contributes to mesodermal tissue development [10].

The word 'stem cell' was initially used toward the end of the 19th century in relation to essential embryological inquiries, particularly concerning the persistence of the reproductive material and the formation of the circulatory system [11-13]. The discovery of blood-forming stem cells established them as the quintessential example of stem cells-cells with the capacity for self-renewal via almost boundless growth and to distinguish into specific types of cells. With this modern definition, stem cells can now be identified in various cellular structures, such as the main nerve network, intestines, and skin, the term 'stem cell' is no longer used for early reproductive cells, although it still refers to reproductive lineage stem cells, like immature sperm cells in the male reproductive organs. Notably, recent research indicates that embryonic stem cells might exhibit characteristics with early reproductive cells [14, 15]. Stem cells are central to some of the most intriguing and groundbreaking inquiries in biology and medicine today.

Stem cells, the unique cells with the ability to transform into various categories of specialized cells, have gained substantial attention in the area of regenerative medicine. Dentistry is one area where stem cells hold immense potential to revolutionize treatment protocols and offer patients improved outcomes. We need to explore the current state of stem cell usage in dentistry, its benefits, challenges, and future directions.

Stem cells can be derived from various sources, including tooth pulp, ligament of the gum and even oral mucosa. Dental stem cells are especially attractive due to their proximity to the oral cavity and their ability to differentiate into a range of tissue types such as dentin, bone, and nerve cells. The concept of regenerative dentistry is to use stem cells to regenerate or replace damaged oral tissues, offering patients a solution to conditions that were previously considered irreversible. One of the most widely studied origin of tooth-derived stem cells is dental pulp stem cells (DPSCs). These cells, found in the soft tissue inside the teeth, have demonstrated the potential to form dentin and other tissues. Research has shown that DPSCs can be harvested from extracted teeth, making them an easily accessible source. This has led to advancements in the regeneration of teeth, particularly in cases where the tooth has been compromised due to decay, trauma, or disease [17] (Figure 2).

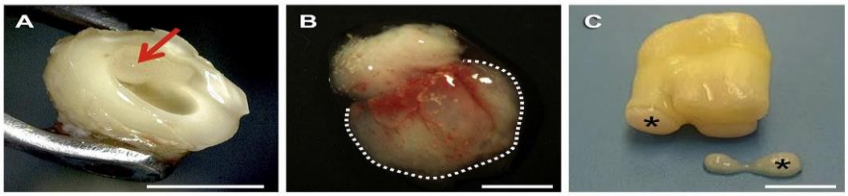

Figure 2: Illustrates the origins of adult stem cells within oral tissues.

A. The pulp tissue (arrow) exposed after a tooth is horizontally cut offers tooth pulp stem cells (DPSCs).
B. The dental follicle (dotted line) from an extracted impacted third molar (10-year-old female)

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gives rise to dental follicle stem cells (DFSCs).

C. The root apical papillae (asterisks) in a removed impacted wisdom tooth (18-year-old male) serves as a source of stem cells from the apical papilla (SCAP). Scale bar: 5 mm [15].

Stem cells of the periodontal ligament (PDLSCs) are another promising source. These are found in the tissues that support the teeth, have shown the capacity to restore periodontal tissues including ligaments, cementum, and alveolar bone. PDLSCs are already being explored for their potential for the management of periodontal disease, which affects millions of people globally. By regenerating lost tissue, these stem cells could help restore the functionality of teeth in patients with severe periodontal damage [18].

Another fascinating application is the utilization of stem cells in dental implants. Dental implants have become a standard procedure for substituting lost teeth, but the effectiveness of implants is often dependent on the amount and quality of the bone in the jaw. Stem cells have the ability to improve bone regeneration at the implant site, improving the success rates of implant surgeries. Recent studies suggest that stem cells may assist in the regeneration of bone tissue, leading to better integration of implants [19]. In the area of tooth regeneration, stem cells offer the possibility of growing entire teeth in the laboratory. Researchers have successfully cultured DPSCs to grow structures resembling teeth in vitro. This breakthrough, while still in early stages, could eventually lead to the ability to regenerate fully functional teeth. If successful, this would be a game-changer for patients who have lost teeth due to injury, disease, or congenital issues [20]. In addition to tissue regeneration, stem cells can be utilized in the treatment of temporomandibular joint (TMJ) conditions. TMJ disorders impact the joint that links the jaw to the cranium, leading to pain, dysfunction, and difficulty with movement. Stem cells could be used to repair damaged cartilage and regenerate the joint tissues, potentially reducing the need for invasive surgeries [21]. Despite the promising possibilities, several challenges exist in the clinical application of stem cells in dentistry. One major hurdle is the complexity of isolating and expanding stem cells in a way that ensures their viability and ability to differentiate into the desired tissue type. Additionally, ensuring that these cells are not rejected by the body and integrating them properly into existing tissues is a significant concern [22].

Ethical considerations also contribute to the application of stem cells. While mature stem cells, such as those originating from dental tissues, do not carry the same moral considerations as those associated with embryonic stem cells, there are still debates concerning the prolonged safety of utilizing stem cells in clinical treatments. As research progresses, regulations will need to evolve to ensure the safe and ethical use of stem cells in dental procedures [23]. Furthermore, the cost of stem cell-based treatments may limit their widespread adoption in dentistry. The process of isolating, culturing, and applying stem cells is resource-intensive, which could make these treatments expensive for patients. However, as technology advances and techniques become more streamlined, the costs may decrease, making stem cell-based therapies more accessible to a broader population [24].

The use of stem cells in dental field also opens up the possibility of personalized treatment. By using a patient's own stem cells, the risk of immune rejection is minimized, and the treatment can be tailored

to the individual's specific needs. This personalized approach could result in better outcomes and faster recovery times [25]. The integration of stem cells with other technologies, like 3D printing, holds the potential to further enhance the field of regenerative dentistry. 3D printing could be used to create scaffolds or templates that direct the proliferation and specialization of stem cells into specific substance types. This could lead to more precise and effective regenerative procedures [26]. As research into stem cells in dentistry continues to evolve, there is potential for the development of new materials and techniques that can better support tissue regeneration. For instance, bioactive scaffolds that release growth factors could be used in combination with stem cells to accelerate the healing process and improve tissue quality [27]. While stem cell therapy in dentistry is still largely experimental, the ongoing advancements in the field are promising. Research studies are in progress to evaluate the safety and effectiveness of stem cell-driven treatments for various dental conditions. These trials will provide valuable data on how stem cells can be applied to address issues like tooth deprivation and periodontal disease, and TMJ disorders [28].

In the near future, stem cell-based treatments could become an integral part of dental care, offering patients a more natural and effective solution to dental problems. The ability to regenerate damaged tissues and even grow new teeth would significantly enhance the well- being of numerous patients [29]. The possible uses of stem cells in dentistry are vast, ranging from tissue regeneration to the creation of fully functional teeth. However, much work remains to be done to refine these techniques and bring them into mainstream practice. Continued research, clinical trials, and technological innovations will be crucial in realizing the full potential of stem cell therapies in dentistry [30].

In conclusion, stem cells offer significant potential in the field of dentistry, offering a new frontier in regenerative treatments. Although there are challenges to overcome, the future of dentistry could see significant improvements in patient care, with stem cells playing a key role in repairing and regenerating oral tissues. As research continues to progress, stem cells may ultimately become a cornerstone of dental treatments, revolutionizing the way we approach dental care [31].

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