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Biological Aspects of Periodontal Wound Healing in Autotransplanted Teeth

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Abstract: Autotransplantation is surgical relocation (transplantation) of a tooth from its original position within the alveolar ridge to another location within the alveolar ridge. However, a successful outcome always begins with a well-established indication and a proven justification for the treatment in question. Literature examples state for broad biological potential of this procedure and demonstrates that, by following fundamental criteria and principles, success can be achieved even in complex clinical cases that would otherwise be considered difficult to resolve. AT can be accurately described as a combined periodontological, endodontic, and surgical intervention. The type of cells that proliferate along the root surface following a periodontal injury determines the nature of the attachment that will form and the manner in which the wound heals. Impaired healing results in complications such as root resorption—which may manifest as inflammatory resorption or replacement resorption (leading to ankylosis)—pulp necrosis, impaired periodontal healing, etc. The use of A-PRF is considered to promote wound healing processes and angiogenesis. In cases of autotransplantation, its use is believed to enhance the natural revascularization process of the transplanted tooth. A key factor that significantly enhances the chances of success in autotransplantation is the presence of viable, undamaged periodontal ligament cells, which facilitate healing and the stabilization of the tooth within the alveolus. Incorporating A-PRF into the protocol introduces an additional biological dimension that further improves and alters healing pathways and processes.

Keywords: *Autotransplantation- AT, Periodontal Ligament - PDL, Platelet Rich Finrin- PRF.*

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I. INTRODUCTION

To establish a framework—or a definition—for the term "autotransplantation," one could briefly state that it involves the surgical relocation (transplantation) of a tooth from its original position within the alveolar ridge to another location within the alveolar ridge (Figure 1). Naturally, this definition is not exhaustive; further clarification is required to provide a complete picture of the procedure. The process entails the avulsion (extraction with minimal trauma) of the donor tooth, followed by its transfer into either an existing or a newly created socket (the recipient site). The donor tooth may be erupted or impacted, vital or non-vital, and may have either a fully or incompletely developed root. The recipient site may be a fresh extraction socket—with or without an existing infection—and may have all four walls intact or one or more walls missing. Autotransplantation can be classified as delayed (performed several weeks after an extraction), immediate (where the extraction of the tooth to be replaced, the extraction of the donor tooth, and the placement of the donor tooth into the recipient site all occur in a single session), or as transplantation into a newly created socket (a surgically prepared site). [1, 2].

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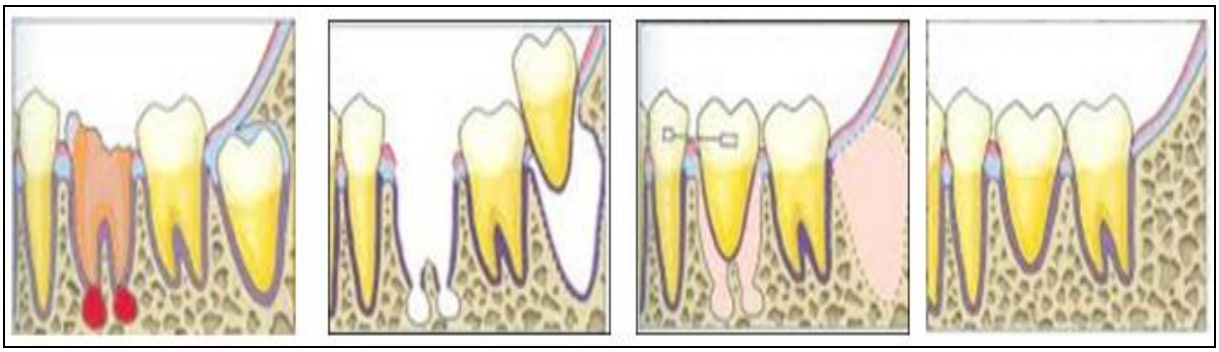


Fig 1 Schematic Representation of Autotransplantation
(Images Taken from http://www.myhealth.gov.my/ en/tooth-transplantation/)

Tooth autotransplantation (AT) has been performed for many years, though with varying degrees of success. As far back as the era of the pharaohs, attempts were made to transplant teeth from slaves to pharaohs; however, due to a lack of histocompatibility, these interventions—as expected—ended in failure. When the procedure is performed with care, a thorough understanding of the underlying biological principles, and the application of appropriate clinical techniques, it can be highly successful [3, 4].

The foundations of modern tooth autotransplantation were subsequently established by M. L. Hale, who documented the first such procedure in 1954 [4], while Slagsvold and Bjercke, at the University of Oslo in 1960, developed the first surgical protocol for this intervention [5]. This significantly enhanced the predictability and success rate of the treatment—a fact subsequently confirmed by numerous long-term studies on the subject.

Advances in cellular biology and the evolution of surgical techniques over recent decades have substantially improved the success of autotransplantation, establishing it as a reliable option for replacing missing teeth [6].

➢ *Indications*

The success of any medical treatment depends on many factors. Through their scientific work and research evidence, researchers consistently strive to synthesize these into a comprehensive list of factors, criteria, procedures, and protocols. However, a successful outcome always begins with a well-established indication and a proven justification for the treatment in question.

Listed below are the recognized indications for tooth autotransplantation (AT), identified based on available scientific literature [1, 2, 6]:

- Replacement of a missing (extracted) tooth. The most common application of tooth autotransplantation is to replace a missing tooth. This is particularly important in young patients, as the procedure helps preserve the integrity of the alveolar bone and masticatory (chewing) function.
- Replacement of a hopeless, non-restorable tooth. In cases where all therapeutic options have been exhausted—such as teeth with extensive carious destruction—this procedure allows for the immediate replacement of the extracted tooth, thereby preserving the level of the alveolar bone.
- Management of traumatic tooth loss (avulsion). Traumatic tooth loss, especially in the anterior (front) region in young patients, is an extremely stressful event. In these cases, autotransplantation of teeth facilitates the immediate resolution of tooth loss, rapidly restoring aesthetics, function, and the supporting tissues (both bone and soft tissue). Most commonly, premolars or third molars are used as donor teeth to replace missing incisors.
- Treatment of congenitally missing teeth. This is most commonly performed in patients lacking lateral incisors or second premolars. Premolars are the most frequently used donor teeth, as they offer the best match regarding root morphology and the aesthetics of the anterior teeth.
- As part of orthodontic therapy. It can be used as an adjunctive procedure to facilitate and accelerate orthodontic treatment in cases of severe malposition or ectopic tooth placement.
- As an adjunct to regenerative procedures. In cases involving significant loss of alveolar bone due to periodontal or periapical inflammation, autotransplantation (AT) can be used to supplement regenerative procedures involving PRF (Platelet-Rich Fibrin) and bone grafts. Viable cells from the periodontal ligament of the donor tooth effectively promote bone regeneration within large bone defects.
- Management of impacted teeth. AT can also be successfully employed for impacted teeth that are not amenable to orthodontic treatment—such as canines or third molars in highly unfavorable positions. Through AT, these teeth can be placed into their ideal positions, thereby significantly accelerating subsequent orthodontic therapy.

Dental implants have established themselves as the leading treatment for replacing lost teeth. However, they are not always a viable option for the patient; in such cases, autotransplantation can serve as a good alternative for replacing missing teeth. In adult patients, autotransplantation is often preferred, primarily for financial reasons. Even if a tooth transplant fails, it still functions as a "space maintainer" for a future implant. The use of dental tissue as a substitute or for bone augmentation is a growing trend [7].

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The literature also contains examples of rare indications for tooth autotransplantation. One such example is a study by Osterne R. L. et al., which describes a case where autotransplantation, combined with orthodontic treatment, was used to reconstruct the alveolar bone following a marginal mandibular resection. The authors report success in reconstructing a mandibular bone defect—specifically in the region of the lower left canine and premolars—following a mandibular resection performed to treat an ameloblastoma. This was achieved through the autotransplantation of third molars with incomplete root development, followed and supported by orthodontic treatment [8]. This example highlights the broad biological potential of this procedure and demonstrates that, by following fundamental criteria and principles, success can be achieved even in complex clinical cases that would otherwise be considered difficult to resolve.

➢ *Contraindications*

Contraindications can be absolute—where the procedure cannot be performed at all—or relative—where the procedure may be performed after a certain period and once appropriate conditions have been established. Depending on their nature and location, contraindications can be classified into the following categories [9, 10]:

Local contraindications related to the recipient site:

- Active infection or inflammation: The recipient site must be free from acute infection, abscesses, or severe periodontal disease.
- Insufficient bone width: The recipient site must have adequate buccolingual and mesiodistal bone width to support the donor tooth.
- Inadequate soft tissue: A lack of adjacent soft tissue necessary to achieve primary closure of the surgical wound.
- Contraindications related to patient health and compliance:
- Systemic diseases: Uncontrolled systemic diseases that compromise healing and the immune response (e.g., uncontrolled diabetes mellitus or immunodeficiency).
- Medication-related risks: Patients taking certain medications that affect bone metabolism (e.g., intravenous bisphosphonates), which may lead to osteonecrosis of the jaw.
- Poor oral hygiene and smoking: Low motivation to maintain oral hygiene, poor oral hygiene, or excessive smoking significantly reduce the success rate and increase the risk of graft loss.
- Bleeding disorders: Severe coagulopathies, as well as the use of anticoagulants, pose a significant risk during surgical extraction and transplantation.
- Contraindications related to donor teeth:
- Unfavorable root anatomy: Donor teeth with severely dilacerated, curved, or fractured roots, which complicate atraumatic extraction.
- Damaged periodontal ligament (PDL): If the PDL of the donor tooth is compromised or necrotic, the tooth may fail to establish successful periodontal attachment and will likely undergo replacement resorption (ankylosis).

II. BIOLOGICAL ASPECTS OF AT (PERIODONTAL AND PULPAL HEALING)

Tooth autotransplantation is undoubtedly a multidisciplinary procedure, requiring knowledge and skills from various dental specialties. When considering the procedure in terms of the tissue injury inflicted during the process—and the subsequent tissue healing—it can be accurately described as a combined periodontological, endodontic, and surgical intervention. The intervention itself involves injury to the periodontal tissue—primarily damage to the periodontal ligament—as well as injury to, or the disruption of the biological continuity of, the pulpal tissue.

➢ *Periodontal Wound Healing*

The healing of periodontal wounds is considered a more complex process compared to the healing of epidermal wounds. As previously mentioned, the periodontium comprises cementum, the functionally oriented periodontal ligament (PDL), alveolar bone, and the gingiva. The interplay and interconnection of these four tissues constitute a highly complex structural and functional entity.

The cell lineages involved in the healing of periodontal tissues belong to a mixed population, including endothelial cells, fibroblasts, osteoprogenitor cells, blood cells, and immune system cells. In this context, it is particularly important to note that the most primitive cells within these systems are classified as stem cells. They are characterized by their capacity for extensive self-renewal, their responsiveness to regulatory factors, and their ability to differentiate into various specialized cell types within the tissue.

The type of cells that proliferate along the root surface following a periodontal injury determines the nature of the attachment that will form and the manner in which the wound heals [11, 12]. In this race for dominance, the cell type that colonizes the root surface first will dictate the subsequent course of healing. During the healing process, the root surface may be colonized by four distinct cell types:

- Epithelial cells – If the epithelium proliferates along the root surface before other tissues reach the area, the result will be a long junctional epithelium.
- Fibroblasts originating from the gingival connective tissue – the result will be fibers running parallel to the tooth surface, along with remodeling of the alveolar bone, but without attachment to the cementum.
- Cells originating from the bone (osteoblasts and osteoclasts) – root resorption and ankylosis may occur.
- Cells originating from the periodontal ligament – new formation of cementum and periodontal ligament takes place.

Histologically, the PDL consists of a dense network of collagen fibers combined with fibroblasts, cementoblasts, osteoblasts, and undifferentiated mesenchymal cells (multipotent cells). This combination of tissues anchors the tooth to the alveolar walls and aids in the regeneration of bone, cementum, and surrounding tissues following an injury (such as in the case of autotransplantation). During

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autotransplantation, preserving the viability of these cells is crucial. Damage to or desiccation of the PDL can hinder reattachment and lead to complications such as root resorption or ankylosis. To maintain cell vitality, the donor tooth must be carefully extracted and temporarily stored in appropriate solutions, such as Hank's Balanced Salt Solution (HBSS) or physiological saline. These solutions support the activity of PDL cells, facilitating tissue regeneration and integration into the new alveolar socket [10].

According to Crooss D. et al., PDL healing depends on the number and viability of periodontal ligament stem cells attached to the root surface. However, when the recipient socket and the donor tooth do not fit perfectly, the socket and/or the occlusal surface of the tooth may require additional trimming and preparation, which extends the extraoral time. To maintain the viability of the stem cells, minimal manipulation of Hertwig's root sheath on the donor root is required, and the extraoral time for the donor tooth should be limited to 5 minutes [13].

The biomechanical status of the tooth within the new alveolus significantly influences the treatment outcome. Adequate stabilization of the transplanted tooth is essential for maintaining its position and facilitating the functional reattachment of the periodontal ligament (PDL). Excessively rigid fixation may impair natural remodeling, whereas excessive mobility can increase the risk of root resorption or displacement. Consequently, controlled stabilization—which permits limited physiological movement—yields an optimal outcome.

Overall, the histological and biological basis of tooth autotransplantation illustrates the synergistic relationship between the integrity of the PDL, the regeneration of the pulp and dentin, and the remodeling of the alveolar bone. These natural processes contribute to a more biologically adaptive outcome compared to synthetic alternatives, such as dental implants [6].

➢ *Possible Outcomes During Periodontal Ligament Healing*

- *Regeneration*. The ideal scenario involves the formation of a vital periodontal ligament (PDL) on the root surface. In this case, complete healing can occur, resulting in the maintenance of a vital and functional PDL. Atraumatic tooth extraction is crucial for preserving the viability of the PDL and the cementum. The cementum forms a protective layer covering the root, to which a new PDL can attach. Without it, the root is at risk of resorption by osteoclasts derived from the bone.
- *Replacement resorption / ankylosis*. If the area of necrosis involving the cementum and the periodontal ligament (PDL) is too extensive, healing occurs via bone replacement, resulting in direct contact between the root surface and the adjacent alveolar bone.
- *Infection-related resorption (also known as inflammatory resorption)*. This type of resorption occurs when there is a concurrent infected root canal and damage to the adjacent cementum, allowing for direct communication—via the dentinal tubules—with the periodontal ligament space. Inflammatory byproducts from the root canal trigger an inflammatory response on the root surface, which promotes further resorption of the periodontal ligament and cementum. Unlike replacement resorption, inflammatory resorption can be halted by the timely initiation of root canal therapy and the removal of the infected pulp. It progresses much more rapidly than replacement resorption; therefore, careful monitoring is required to ensure early detection and treatment.

➢ *Possible Outcomes of Pulp Healing.*

- *Revascularization and obliteration of the pulp canal*. The pulp of any transplanted tooth may undergo ischemic damage and become necrotic. However, in teeth with an open apex, the pulp canal space can be revascularized through the ingrowth of capillary vessels via the apex. This revascularization progresses at a rate of 0.5 to 1 mm per day. Following revascularization, calcification of the pulp canal space occurs, manifesting radiographically as progressive obliteration of the pulp canal. It should be noted that the tooth still contains vital pulp tissue and typically yields a positive result on vitality testing.
- *Pulp necrosis*. Pulp healing cannot be expected if the apical opening of the donor tooth is less than 1 mm in diameter; consequently, a tooth with a closed apex will most likely require endodontic therapy. This does not constitute a contraindication for the transplantation of teeth with closed apices, although many clinicians avoid this procedure, as scientific evidence associates it with poorer outcomes. Pulp necrosis in an immature tooth presents an endodontic challenge. [14].

III. EVALUATION OF SUCCESS

The primary goals of tooth transplantation are the absence of ankylosis and the survival of the periodontal ligament (PDL). The criteria for successful tooth transplantation are divided into two main categories: radiographic criteria—including a normal width of the periodontal space surrounding the transplanted tooth, a radiopaque line of the alveolar bone (lamina dura), absence of root resorption, normal periapical healing, absence of apical infection, and a crown-to-root ratio of less than one to ensure the tooth remains functional—and clinical criteria—including normal mobility of the transplanted tooth, absence of periodontal pockets, no signs of inflammation, normal tooth function, absence of pain, a positive vitality response (if the tooth was vital), normal root development, and a normal sound upon percussion [10].

➢ *Complications*

The survival and prognosis of autotransplanted teeth are similar to those of dental implants. However, it must be emphasized that certain complications can compromise the clinical outcome of these teeth. These include complications such as root resorption—which may manifest as inflammatory resorption or replacement resorption (leading to ankylosis)—pulp necrosis, impaired periodontal healing, etc. [1, 2, 15].

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Factors contributing to root resorption. There are numerous factors that influence root resorption during tooth autotransplantation. Proper management of these factors can improve the success of the procedure.

- *Extraoral time.* Prolonged exposure leads to the death of PDL (periodontal ligament) cells, increasing the risk of resorption. Immediate transplantation, or storing the tooth in HBSS or physiological saline during the operation, protects the PDL and reduces this risk.
- *Trauma during explantation*. The use of excessive force or improper techniques can damage the PDL and cementum, compromising the root surface and increasing the risk of resorption. Gentle, atraumatic extraction helps protect these structures.
- *Condition of the recipient site.* Infections, a lack of bony support, or poor preparation of the alveolus cause inflammation, increasing the risk of resorption. Maintaining aseptic conditions, properly shaping the alveolus, and ensuring an adequate volume of bone help prevent this.
- *Stability of the recipient site.* Strong, rigid stabilization prevents the reattachment of the PDL, while excessive mobility delays healing, increasing the risk of ankylosis or resorption. Appropriate stabilization ensures a successful transplantation [6, 10, 16, 17].

IV. USE OF PLATELET-RICH FIBRIN (PRF) IN AUTOTRANSPLANTATION

In a comprehensive paper, Avila-Ortiz G. et al. address the topic of using biological materials in periodontology and implantology. They state that the ultimate goal of periodontal and implant therapy is to preserve, improve, reconstruct, and maintain the tissues that support teeth and dental implants, in order to achieve predictable, successful, and long-term health, comfort, function, and aesthetics. To overcome some of the limitations of conventional therapeutic approaches, clinicians have been utilizing tissue engineering concepts—since the late 1990s—to improve the outcomes of periodontal therapy in daily practice. Over the past three decades, various bioengineering strategies designed to stimulate the formation of new oral tissue—including the use of biological agents—have been described and tested in both preclinical and clinical settings [18].

The use of A-PRF is considered to promote wound healing processes and angiogenesis. In cases of autotransplantation, its use is believed to enhance the natural revascularization process of the transplanted tooth. Furthermore, storing the donor tooth in PRF exudate while it is outside the alveolar socket can help preserve the vitality of cells from both the pulp and the periodontal ligament (PDL), thereby improving the clinical outcome [19].

PRF stimulates angiogenesis through the migration, proliferation, and phenotypic alteration of endothelial cells. It also promotes cellular mitosis and induces osteogenesis without triggering an inflammatory response. These effects occur through a gradual process lasting anywhere from at least one week [20] up to four weeks [21].

Within 14 days, PRF can induce robust and sustained differentiation and stimulation of both osteoblasts and fibroblasts [22].

The sustained release of key growth factors, the flexible trimolecular fibrin matrix, and the matrix's capacity to facilitate cytokine binding and cellular migration are the reasons why PRF is gaining attention in regenerative studies. Case reports on the use of PRF in combination with mineral trioxide aggregate (MTA) for the management of cases with open apices have revealed accelerated periapical healing and apical bone formation [23].

V. CONCLUSION

Based on the literature reviewed and the research conducted during the preparation of this topic, several conclusions can be drawn.

Predictive factors for transplant survival are directly linked to the preservation of cell vitality within the periodontal ligament of the donor tooth. Improper handling of the tooth during the procedure, as well as the duration of its time spent extraorally, can damage the ligament structure, leading to various postoperative complications. Consequently, this procedure requires a very gentle, atraumatic extraction of the tooth and careful handling throughout the intervention.

A key factor that significantly enhances the chances of success in autotransplantation is the presence of viable, undamaged periodontal ligament cells, which facilitate healing and the stabilization of the tooth within the alveolus. Pulp recovery is possible only if the diameter of the apical foramen exceeds 1 mm.

Incorporating A-PRF into the protocol introduces an additional biological dimension that further improves and alters healing pathways and processes. The fibrin matrix acts as a natural scaffold, promoting organized tissue regeneration while simultaneously delivering concentrated autologous growth factors directly to the healing tissues. However, the available literature lacks works that provide a systematic and broader perspective on this issue; consequently, we conclude that this topic requires more detailed attention and investigation in order to reach statistically significant conclusions.

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