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Master's Thesis

# Tooth Auto-Transplantation-Literature Review: Analysis of a Method

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**Abstract**

Tooth autotransplantation is a surgical procedure involving the transplantation of a tooth or tooth germ from one alveolar site to another alveolar process within the same person's mouth. Although this technique has been performed for centuries, it remains underdocumented and not widely known. This review examines the critical determinants, indications, advantages and disadvanatges of tooth autotransplantation, as well as complications and the clinical success rates. Teeth may be lost due to several reasons, including deep caries, apical pathologies, cervical resorptions, and severe dental injuries. The transplanted tooth functions are to replace a tooth that is not worthy of preservation, functionally, biologically, and aesthetically. The success rates of autotransplantation are generally high across all age groups. Higher success rates are observed in children and adolescents with not completely closed apical foramen, in comparison to those with completed growth. Even if autotransplantation fails, the surrounding bone and soft tissue anatomy remain suitable for subsequent prosthetic or implant treatment. Successful outcomes of the procedure rely on a careful patient and tooth selection. The literature indicates that tooth autotransplantation is a viable and cost-effective technique.

**Keywords**

autotransplantation; clinical indications; sequence and treatment options; meta-analysis; Success rate;

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# 1. Introduction

## 1.1 Problem statement

Tooth autotransplantation is described as a controlled, sterile avulsion and re-implantation of a tooth from one site to another in the same individual. A tooth from one donor area is repositioned to a site in where its function and esthetic would be more relevant. It is a technique suggested in cases of tooth loss, due to deep caries, severe trauma, periodontitis, or apical pathologies also in cases of agenesis or tooth impaction (1). Following tooth loss, various therapeutical approaches are available to fill the resulting gap. Once the jaw and body growth has ceased, a fixed prosthesis can be fabricated to restore the missing tooth. In comparison to the fixed prosthetic options, such as osteointegrated dental implants, successfully autotransplanted teeth provide continuous eruption, have a vital periodontium, preserve an interdental papilla and alveolar bone volume, and have the potential of tooth movement or physiological forces. The usage of fixed prosthetics is contraindicated for pediatric and adolescents, due to the ongoing process of bone growth. In addition to orthodontic treatment for gap closure, the tooth transplantation technique might be an option. The decision is made according to the individual case. The potential failure of tooth transplantations can be attributed to various risk factors such as pulp necrosis, inflammatory or replacement root resorption, ankylosis, and compromised periodontal healing. (2). There are several factors that influence the survival and success rates of autotransplanted teeth. The success of tooth autotransplantation has been linked to several factors, including patients-specific factors, the characteristics of the donor tooth, the recipient site and the procedural technique employed (3). In absence of definitive evidence supporting a causal relationship between these factors and the eventual success and survival of transplantations, it is not possible to, draw a definitive conclusion, regarding the majority, of these factors. Recent systematic reviews and meta-analyses investigating the outcomes of autotransplantation of teeth with complete root formation have reported a very low incidence of complications and failure, specifically related to infection-related root resorption and ankylosis. Despite the favorable outcomes reported in recent studies, it is necessary to perform endodontic treatment of the transplanted tooth with complete root formation to prevent the development of periodontal or pulp-related diseases. In cases of tooth autotransplantation involving teeth with incomplete root closure, endodontic treatment is

typically not required, due to presence of open apex, and the possibility of pulp reinnervation and revascularization (4).

## 1.2 Research objective

The aim of this literature research is to accomplish the following objectives:

- Describe the tooth autotransplantation procedure,
- Analyze the prognostic factors associated with autotransplantation,
- Evaluate the -outcomes of tooth autotransplantation and determine the overall survival and success rates.

## 1.3 Methodology / Literature search strategy

The two electronic databases were selected for the literature review-, including Pubmed and Google Scholar. Only studies published in English between 2012 and 2022 were considered for the analysis. Retrospective and longitudinal studies were included. The research was conducted, using MESH terms, synonyms, and relevant keywords such as “autotransplantation; clinical indications; sequence and treatment options; success rate; meta-analysis”. The search yielded a total of 115 results with additional five articles from google scholar. Abstracts were read first, after this relevant full text articles were read. Finally, 71 references were selected.

## 1.4 Structure

In this thesis a brief historical overview of tooth autotransplantation will be presented, followed by a classification of the procedure and an analysis of its advantages and disadvantages. The therapeutic indications and contraindications will be also discussed. The main part of the thesis will focus on describing the clinical protocol and surgical procedure of tooth autotransplantation. Post-surgical requirements and potentially resulting complications will also be addressed. To better understand the success and survival rates of this technique-sensitive procedure, recent clincial results will be analyzed and new technologies for simplifying the surgery will be presented. The thesis will conclude with a summary of findings and a bibliography of relevant sources.

# 2. Historic overview

Tooth autotransplantation has begun as the practice of allotransplantation, which involved the transplantation of teeth between two different people. The evidence of tooth autotransplantation can be traced back to ancient Egypt, where mummies have been discovered with human teeth that had been transplanted from other individuals. Slaves were forced to give up their teeth to their pharaohs. Until the 18th century, tooth transplantation was performed exclusively on the upper classes, who could afford expensive treatment in place of dentures. In the past, however, dentistry was mainly concerned with extracting teeth and providing prostheses in edentulous areas. One of the earliest techniques was introduced by Ambroise Paré in 1561, asserting that decayed teeth could be replaced by extracted teeth from another individual. In 1772, surgeon John Hunter primarily recorded the success of transplantation between humans. Hunter pointed out that the transplanted tooth should ideally be smaller than the alveolus, and if it is not, it should be adjusted to fit into the alveolus. In his publication, the "Natural History of Human Teeth", John Hunter described an experiment in which animal or human teeth were transplanted into a cock's comb. He observed that the transplanted tooth exhibited regeneration of blood vessels in both the dental pulp and periodontal ligament. This experiment provided early evidence of the potential for tooth autotransplantation and the ability of transplanted teeth to establish connections with the surrounding tissues. There was no knowledge of disease transmission and immune compatibility at that time. John Hunter, despite his contribution to the field of tooth transplantation, failed to recognize the importance of the procedure in the transmission of syphilis, as the result, the procedure, which was popular in the 18th century, became infamous in the history of dentistry (5). From the 1950s, scientific work was focused more on autografts and the term is known as autotransplantation. The early concept of autotransplantation focused on the surgical repositioning of the undeveloped third molar into the socket of previously extracted severely decayed unrestorable first molar, requiring traumatic surgical extraction of the donor teeth. This often resulted in excessive damage to the periodontal ligament and cementum leading to poor outcomes. However, the success rate at that time was only about 50%. In 1970, animal studies played a significant role in advancing the field of tooth autotransplantation, leading to improved surgical techniques and a better success rate. Researches on monkeys have led to progresses in the knowledge of the nature of cementum and periodontal ligament, as well as the importance of careful atraumatic extractions. This has led

to a considerable improvement in the success rate and an increase in the popularity of the method of autotransplantation (6).

# 3. Classification

Autotransplantation is classified into three groups: conventional, intra-alveolar transplantation and intentional replantation.

Conventional tooth autotransplantation can be defined as the "transplantation of teeth from one site to another in the same individual, involving the transfer of embedded, impacted or erupted teeth into extraction sites or surgically prepared sockets" (7). Surgical uprighting and surgical extrusion also follow the same healing process as autotransplantation, these procedures can be defined as intra-alveolar transplantations and are described as surgical procedures in which a residual portion of tooth structure is repositioned in a more coronal/supragingival position within the same alveolus in which the tooth was located originally. It is an alternative treatment method for teeth with crown-root fractures, cervical root fractures, and subgingival caries (8,9). Moreover, intentional replantation could be considered a form of transplantation. Intentional replantation can be performed for an endodontic problem that cannot be resolved by a conventional non-surgical or surgical approach. The procedure involves extraction of the tooth, cutting off 3mm of the apex, preparing the root canal, retro-filling it extra-orally and then replanting the tooth into the original socket without changing its original position (10-12).

# 4. Advantages and Disadvantages

## 4.1 Advantages of autotransplantation

Autotransplantation can be considered a better alternative to the fixed or removable prosthesis, due to the avoidance of the preparation of the adjacent teeth, and cost-effectiveness in comparison to other treatment possibilities like implants or fixed prostheses (13). Successful autotransplantation presents various biological advantages, such as improved aesthetics, dentofacial development, speech, arch form, arch integrity and masticatory function (14). Autotransplanted teeth, unlike prosthetic restorations, provide proprioception during function and have a very good prognosis in children/adolescents (14-16).

### 4.2 Disadvantages of autotransplantation

However, autotransplantation involves more extensive surgical intervention compared to conventional tooth extraction, and the treatment outcome may be challenging to predict. Biological complications such as root resorption, ankylosis, and loss of attachment may result in a complete loss of the transplanted tooth (17,18).

## 5. Indications for tooth autotransplantation

In general, conventional transplantation is indicated when a tooth is unrestorable and a tooth that is not in function, such as a third molar or a malpositioned tooth can be used as a donor tooth. Third molars are often transplanted to the extraction site of unrestorable first or second molars, and if the donor tooth is of appropriate size, transplantation can also be performed in the premolar or anterior regions. Donor teeth are not limited to the third molars, as malpositioned or impacted premolars or canines can also be used as donor teeth.

### 5.1 The criteria for candidate selection

Despite its many advantages, tooth autotransplantation is a very technique-sensitive procedure. Careful selection of individual cases and certain surgical skills are the decisive factors for the success of the procedure. Inaccurate case selection can significantly compromise the efficacy of this treatment option, underscoring the importance of stringent selection criteria when considering autotransplantation for a patient.

For a patient to be considered for tooth transplantation surgery, they must be in good overall health and with an uncomplicated medical history. The candidate needs to demonstrate an excellent level of oral hygiene. Avoidance of smoking is crucial, as this bad habit can adversely affect vascularity and wound healing potential posttransplantation, leading to poor outcomes. Patient compliance and agreement to the procedure are essential factors, that lead to success. Furthermore, identifying a suitable donor tooth and recipient site are crucial prerequisites for the success of the tooth autotransplantation procedure (15, 19-22).

### 5.2 The criteria of the donor tooth

The optimal donor tooth for transplantation should exhibit sound periodontal and pulpal health, should have an incomplete root development, and exhibit normal anatomical features that match

the recipient site without interfering with the occlusion (23). The tooth should also be in a position where it can be removed as less traumatically as possible. Recent advances in three-dimensional imaging techniques have the potential to enhance the success rate of the autotransplantation procedure. Such 3 D imaging can assist in the selection of an appropriate donor tooth through the accuracy of pre-surgical morphological measurements and facilitate the planned atraumatic extraction (17).

The stage of root development is a critical factor for the success rate of autotransplantation. Studies have reported it to be one of the main factors affecting the prognosis of an autotransplanted tooth. The success rate of autotransplantation is highly dependent on the stage of root development of the transplant. Studies have shown that if the transplant root is incompletely formed or has only half to three-quarters of the normal root length at the time of surgery, the average success rate of autotransplanted teeth has been more than 80%. In autotransplantation cases, further root development most likely depends on the health of Hertwig's epithelial root sheath. If Hertwig's root sheath is damaged, future root growth will likely be restricted or inhibited. It has been shown that a half to three-quarter root length, or between seven and nine millimeters with a wide, open apical foramen, is emphasized as the most important factor in achieving the objectives of ongoing root development with the periodontal ligament and pulpal healing. For a tooth with incomplete root formation, revascularization will usually occur (24). After revascularization, pulp obliteration is a usual and natural occurrence that can be observed radiographically within three to six months. Approximately 7-27% of teeth with pulp obliteration may develop pulp necrosis with radiographic evidence of periapical disease. This is a significant advantage in transplanting teeth with incomplete root growth because further endodontic treatment is generally not needed. Lower first and second premolars and upper second premolars are deemed the most successful transplants, due to their favorable root morphology. The transplantation of immature premolars to the maxillary incisor region has been associated with the highest success rate (25).

In teeth with closed root apices, pulp extirpation must be performed between 7 and 14 days after transplantation to avoid the infected necrotic pulp causing inflammatory resorption and early loss. This seems to be justified by the fact that only 15% of teeth with complete root development are revitalized after transplantation, compared with 96% of teeth with incomplete root formation. Critical factors affecting the longevity of an endodontically treated transplant include not only a high-quality endodontic procedure, but also the subsequent restoration with an effective coronal seal.

In the context of tooth transplantation, the most favorable is a smooth, conical single root shape. Teeth featuring very large, widely spread or curved roots prone to mechanical damage to the periodontal ligament during extraction or transplantation, making the procedure more challenging. Controversely, teeth with short roots tend to develop periodontal pockets at the furcation area after the transplantation. The transplantation of multirooted teeth with enamel projection or periodontally involved teeth with attachment loss of more than one-third of roots are contraindicated. If more than two teeth are suitable for transplantation, the choice of donor tooth depends on the shape of the crowns of the recipient tooth (27-29).

### 5.3 The criteria of the recipient site

The recipient site should be free from acute infection and chronic inflammation. The ideal recipient socket should have enough width and height to receive the donor tooth completely. Better healing can be expected if the bone of the recipient socket has periodontal ligament tissue still attached after extraction of the condemned tooth. The recipient site can be improved if needed by enlarging the socket surgically, and in the case of maxillary sockets, sinus lifts may be needed. The ideal recipient site is an extraction socket that is large enough to hold the donor tooth (30).

## 6. Therapeutic indications

The decision to perform tooth transplantation is based on consultation and precise planning with the various dental specialities. In addition to the surgical considerations, input from orthodontic and tooth preservation experts is crucial. It is not uncommon to require orthodontic adjustment of the transplanted tooth position within the dental arch or atomical reconstruction/reshaping of the transplanted tooth in the aesthetic area. Interdisciplinary and multidisciplinary therapy planning is essential for achieving successful treatment outcomes.

<u>Therapeutic indications for autotransplantation:</u> (31-37)

-Tooth loss due to trauma

-Tooth loss due to caries or apical periodontitis

-Impacted teeth

-Ectopic teeth

-infection-related external root resorption

-agenesis of a permanent tooth

-tumors

-iatrogenic causes

-teeth with poor prognosis

| Tooth Requiring Replacement | Common Aetiology for Tooth Replacement | Preferred Donor Tooth |
|---|---|---|
| Central incisor | Traumatic tooth loss<br>Poor prognosis following trauma<br>Ectopic or dilacerated | Premolar<br>Canine |
| Lateral incisor | Hypodontia<br>Trauma | Lower incisor |
| Canine | Ectopic | Premolar |
| Premolar | Hypodontia<br>Developmental anomaly | Premolar<br>Canine<br>Third molar* |
| First permanent molar | Poor prognosis | Premolar<br>Third molar* |

**Table 1.** Uses for autotransplantation based on the tooth that requires replacement (*not commonly used in the UK).

(38)

## 7. Contra-indications for tooth autotransplantation

Elective surgery should be avoided in patients with:

-high risk of postoperative infections

-decreased immune system

-uncontrolled blood clotting disorders

-insufficiently controlled diabetes mellitus

If there is a need for endocarditis prophylaxis (e.g., mechanical heart valve replacement or endocarditis that has already occurred) guidelines, antibiotic prophylaxis should be carried out preoperatively.

Prior to any surgery patients should undergo conservative rehabilitation to address caries, gingivitis and periodontitis. Temporary contraindications for the procedure include local inflammation in the donor or recipient region and inadequate oral hygiene.

In addition, non-adherence to treatment, especially in pediatric patients, represents a relative contraindication for tooth transplantation. Local anesthesia is preferred during the procedure, follow-up appointments for splint removal, a reconstruction of the tooth, or root canal treatment may be necessary. All the steps should be discussed with the patient and his/her guardians beforehand. Hence, patient cooperation is a fundamental requirement for successful treatment outcomes (1, 39).

# 8. Clinical protocol

## 8.1 Examination and diagnosis

The examination of potential transplantation patients includes obtaining necessary radiographs and clinical photographs and performing periodontal and soft tissue evaluation and a cariology assessment. Medical and dental specialty consultations also may be needed. Analysis of donor teeth and recipient sites are included as a part of the examination.

A preoperative CBCT will be required, if the clinician considers necessary the fabrication of a 3D tooth replica of the donor tooth and/or a 3D-printed guiding template (40,41).

Prior to transplantation, potential donor teeth must undergo an analysis to assess their suitability for extraction and appropriateness of shape. In cases where the donor teeth are still developing, they should have reached developmental stage 4 (full development with open apex) or stage 5 (full development with partially closed apex).

Analysis of recipient sites should include the buccolingual and mesiodistal widths of the alveolar ridge at the recipient sites and the location of the maxillary sinus and mandibular canal assessment (42).

## 8.2 Treatment planning

### *8.2.1 Oral hygiene instructions*

Unless caries or periodontal disease causing the non-restorability of the extracted teeth is controlled, transplanted teeth will follow the same fate. Therefore, prior to or simultaneous with surgical procedures, oral hygiene instructions, scaling and root planning should be carried out, and patients must demonstrate competence in maintaining proper oral hygiene.

*8.2.2 Tooth extraction from the recipient site*

The timing of the tooth extraction from the recipient site should be carefully evaluated. The extra-oral time before transplantation is critical and should be kept to an absolute minimum. An extra-oral time of less than one minute has been shown a significant reduction in the risk of pulp necrosis. The vitality of the periodontal ligament is the most important factor for success, which decreases significantly with increased extra-oral exposure.
The indication for tooth extraction from the recipient site prior to transplantation is when a discrepancy between the size of the extraction socket and that of the transplanted tooth is expected, resulting in a lack of the gingival tissue for primary closure. Two weeks after extraction, the extraction socket will be covered with enough soft tissue to achieve primary closure. Transplantation should be performed within two months after the extraction because extensive bone resorption will occur after that period. Therefore, the ideal timing for transplantation is two to four weeks after extraction considering the possibility of preservation of the periodontal ligament as well as the reparability of recipient sites.

The importance of preservation of the periodontal ligament is also a crucial factor for the success of the procedure, the absence of ankylosis and periodontal ligament survival are the primary objectives for a transplanted tooth in a growing individual. The periodontal ligament viability is compromised through extra-oral dehydration or damage. The atraumatic extraction of the donor tooth is paramount to preserve the periodontal ligament and cementum covering the root into which the periodontal ligament attaches. Histological studies show that cementum damage results in direct contact between osteoclasts of the bone and the root surface occur, which leads to replacement resorption or ankylosis (26, 43)

The timing of root canal therapy is also important for further healing and to avoid potential complications.
To prevent inflammatory bone resorption root canal treatment should be accomplished before transplantation or started two weeks after transplantation with completely developed teeth (26, 39).

If transplantation is included as a part of orthodontic treatment, the position or direction of transplanted teeth can be flexible. Orthodontic movement can improve an undesirable size of the recipient site before transplantation. Orthodontic treatment is necessary to correct the

malposition of transplanted teeth or problems of osseous (vertical bony) defects around transplanted teeth (30).

# 9. Surgical procedure

## 9.1 Setting up the instruments

All instruments and necessary materials should be prepared before the procedure, to minimize the surgery time and possible interference. Instruments for a vertical extraction technique may be helpful for a gentle extraction if necessary (39).

## 9.2 Preprocedural administration of antibiotics

To attain desirable antibiotic levels of antibiotic in the blood during and after surgery, it is recommende to admit antibiotics a few hours prior to the procedure. Penicillin is recommended to achieve a rapid increase of antibiotic levels in the blood. Tetracycline is recommended to maintain high levels of antibiotics in the exudate of the sulcus (46).

## 9.3 Disinfection and anesthesia of the surgical site

Professional tooth cleaning should be performed before the surgery and the surgery sites should be disinfected. The donor and transplanted teeth and recipient site are anesthetized at the same time. Generally, local anesthesia (including block) is adequate for both extraction and transplantation.

## 9.4 Extraction of a tooth at the recipient site

The extraction of the tooth at the recipient site should be done prior to the extraction of the donor tooth if the procedure is performed on the same day of autotransplantation. The periodontal ligament of the extraction socket should not be removed; however, any periapical lesion, should be curetted as much as possible. The extraction of the tooth, must be performed carefully not to cause damage to the buccal and lingual/palatal cortical plate surrounding the tooth. In case of congenitally missing teeth or early tooth loss, the recipient site needs to be created surgically (47).

## 9.5 Extraction of the donor tooth

During the extraction of an impacted donor tooth, the alveolar bone over the donor tooth must be removed with a surgical round bur, using sterile saline irrigation to avoid damage to the crown or the root. Before elevation of the donor tooth, an incision is made with a blade around the cervical area into the periodontal ligament for the preservation of as much periodontal ligament on the root as possible. The extracted donor tooth must be stored in physiologic saline or preservative to prevent drying of the periodontal ligament, before the autotransplantation. The ideal solutions for placing the extracted tooth are Hank's Balanced Salt Solution (HBSS), milk and derivatives, saliva and its variants or saline and its variants. The flap of the extraction socket should be closed and sutured to prevent excessive bleeding. In some cases, antiresorptive and regeneration-promoting medicines are recommended to add for transplanted teeth with incomplete root formation. To the physiologic storage, 1mg doxycycline and 1mg dexamethasone are added. In teeth with wide open apical foramen, doxycycline can significantly increase the chance of revascularisation and dexamethasone acts on the root surface of the transplant for reduction of local inflammatory reactions. As a result, resorption around the root surface is less likely to occur. The regeneration of the periodontium is thus additionally supported (71).

The donor tooth should be placed in the recipient site in slight infraposition as soon as possible and not exceeding 15mins, leaving it free from occlusal and articulation forces (48).

## 9.6 Measurement of the donor tooth

The shape and size of the donor tooth are determined extraoral to gather information for the recipient site preparation. This information is difficult to obtain accurately with preoperative radiographs. A caliper or a probe is useful for measuring the mesiodistal or buccolingual width of the crown and the length of the root. The evaluated shape of the root, the length of the root trunk, the development of the root (presence of Hertwig's epithelial sheath), and the amount of preserved periodontal ligament should be evaluated and recorded. An extraoral picture of the donor tooth should be taken mesiodistally and buccolingually (49).

## 9.7 Evaluation of crown width and try-in

At the recipient site, the distance between the adjacent teeth (if they are present) must be measured and compared to the mesiodistal width of the donor tooth before the final preparation of the recipient site. If the donor tooth is too wide, a small amount of enamel can be removed

from the proximal surfaces of the adjacent teeth and the donor tooth. In total, at most 2 mm of enamel should be removed when making these adjustments. Orthodontic treatment is sometimes indicated to control the space.

## 9.8 Preparation of the recipient site

There are two possible scenarios of a recipient site preparation, one scenario when an extraction socket exists, and another when there is no extraction socket. If tooth extraction at the recipient site has been performed within a few weeks before the surgery, an incision is made on the alveolar ridge of the recipient site and in the sulcus of the adjacent teeth with a full-thickness flap to expose 3 to 5 mm of alveolar bone. The incision in the sulcus of the adjacent teeth should be minimal to prevent unnecessary attachment loss. Flap design should be the same even when tooth extraction at the recipient site and transplantation are performed simultaniously to allow better direct vision. A vertical incision is made on the distobuccal area of the adjacent tooth to expose the more alveolar bone. After removing granulation tissue from the extraction socket, the alveolar septum is removed with a rongeur or round bur. If the depth or width of the extraction socket is not sufficient, the lateral or basal wall is re-contoured so that the donor tooth can fit passively.

When the extraction socket does not exist, the recipient site must be surgically prepared, and the exact position and size of the recipient site and direction of transplantation should be well planned by marking the measured data of the donor tooth on the alveolar bone surface. For the exact measurement of a recipient bed, a reference cut is made corresponding to the size of the mesiodistal and buccolingual width of the donor tooth in the cortical bone. Direction and depth are transferred using an implant or trephine bur. The use of the implant bur when the donor tooth is a premolar is recommended, but a surgical round bur should be used when preparing for a molar or making minor adjustments to the recipient site. Preparation of the recipient site should be made with a slow-speed engine (2,000 rpm) while irrigating with saline (45,50,51,58).

If the mesiodistal recipient space is insufficient for the donor tooth (even after maximum enamel removal), it is necessary to plan orthodontic space generation prior to transplantation. When there is insufficient buccolingual bone width, one of two methods is indicated. If the bone width is significantly less than ideal due to bone resorption, cortical bone can be removed using a bur and bone chisel. It is then placed back around the transplanted tooth roots, with the expectation of osteoinduction and bone regeneration. In cases where the insufficiency is minimal,

mechanical methods such as the use of an osteotome or green-stick fracture method may be used to increase the bone width after the recipient site has been prepared.

When the sinus floor is low and the height of the bone is shorter than the length of the donor tooth, a sinus lift procedure is indicated.

- The recipient site is prepared up to the cortical bone subjacent to the sinus floor.
- The incision line is made with a round bur on the cortical bone in the sinus floor, with care not to damage the Schneiderian membrane (sinus mucosa).
- The cortical bone plate is slightly lifted into the sinus using an osteotome.
- The Schneiderian membrane is gradually loosened from the sinus floor and gently lifted from the space created along the incision line of the cortical bone (39,43).

## 9.9 Try-in and plantation of the donor tooth

The donor tooth needs to be tried at the prepared recipient site. Changing the direction of the donor tooth by rotating it 90 degrees helps to find a better fit if the initial direction is not possible. If the depth or length of the prepared recipient site is not adequate, an adjustment must be made accordingly by removing bone with round surgical burs. During plantation, care must be taken not to mechanically damage the periodontal ligament of the donor tooth by pushing it into the recipient area (44, 45).

## 9.10 Trimming and suturing of the flap

After the try-in of the donor tooth in the recipient site, the fit of the gingival tissues around the donor teeth is checked. The success of transplantation depends on the primary closure of the gingiva around the donor tooth. If excess soft tissue is present, the excess is trimmed and the remaining soft tissues are fitted around the donor tooth, making sure that adequate keratinized gingival tissue is available. If there is minimal keratinized tissue at the site, the fitting of the tissue must be done by beveled incision to preserve all keratinized gingival tissue.

When a third molar is transplanted to the area of an adjacent second molar, it may be difficult to obtain a tight fit of the gingival tissue on the distal aspect of the donor tooth. By making a releasing incision, the tissue flap can be brought to a more desirable tight fit to the tooth. It is easier to suture the vertical incision area or proximal area without the donor tooth in place (the donor tooth can be preserved in physiologic saline). Plantation of the donor teeth after the suture has been placed is not difficult because of the elasticity of the gingival flap; a better fit can be obtained this way (52,53).

## 9.11 Fixation and occlusal adjustment of the donor tooth

The type of fixation and its duration depends on various factors. Clinically, stability is important if the attachment needs to be regained. Although it has been suggested that a long period of fixation after replantation may induce ankylosis, whether this applies to transplantation is questionable. The decision to use wire and bonding resin or a suture for the fixation of transplanted teeth must be made based on the needs of each case.

Fixation with wire and resin is indicated when it is difficult to stabilize the transplanted tooth because the roots are short or it fits loosely in the recipient site. After suturing, the transplanted tooth is fixed to the adjacent anchor tooth (one tooth is sufficient) with acid etched and bonded composite resin and flexible wire on the buccal or lingual side. Fixation with wire and resin also helps retain the surgical dressing, which is the next step. It stabilizes the transplanted tooth during endodontic treatment, which should be started 2 weeks after transplantation. Fixation should be removed in 1 to 2 months.

Fixation with a suture is an easy and effective stabilization when the transplanted tooth is stable in the recipient site. The gingival tissue is the anchor in this case and a full-thickness flap should not be utilized for this purpose. Periosteum under the gingiva or gingiva around adjacent teeth must be utilized. The suturing of the tissue and the use of sutures for stabilization requires attention to the details and should be carefully planned prior to the surgical procedure. When fixation is performed with suture, an occlusal adjustment must be completed before the fixation. The suture should be removed in 5 days (53-56)

## 9.12 The occlusal adjustment

The occlusion must be checked to ensure that no occlusal contact is present. If a suture is used for stabilization, the occlusal contacts should be reduced prior to tying the suture. If a wire split is used, the adjustment is made after placing the splint. The occlusal surface of the donor teeth must be shaped, unless the excessive occlusal discrepancy is expected, or suture is utilized for fixation. The periodontal ligament must be protected with gauze soaked in physiologic saline during the adjustment. If the opposing tooth is extruded, it must be recontoured prior to the surgical procedure.

### 9.13 Radiographic evaluation

After the plantation and fixation radiological evaluation is mandatory to check the results and document the initial results.

### 9.14 Surgical dressing and home care instructions

Reattachment of the periodontal ligament from the root of the donor tooth (at the crest of the bone) to the gingival tissues is the first step in healing. Prevention of infection from salivary bacteria is important for the reattachment in this area to be predictable. The transplanted tooth should be protected with a surgical dressing for 4 to 6 days after the procedure to enhance healing around the cervical area. Three days of administration of tetracycline after the procedure seems to be effective clinically. After 4 to 6 days the dressing and sutures should be removed and the tooth and surrounding soft tissues cleaned with a cotton swab. The patient should be instructed to brush the area gently (39).

### 9.15 Removal of the splint

The fixation is removed 1 to 2 months after the procedure in cases of fixation with wire and resin. At the time of splint removal, the transplanted tooth should be stable. Root canal treatment (RCT) of the transplanted tooth should be initiated before removing the splint. The following are the recommended procedures after completion of the transplant surgery: RCT, orthodontic treatment, and final restoration (54).

### 9.16 Root canal treatment in transplanted teeth

Root canal treatment is necessary for the fully developed donor tooth because healing of the pulp cannot be expected after apical closure. In the case of an impacted donor tooth, RCT is performed two weeks after the transplantation. After preparing the root canals, an interim dressing of calcium hydroxide is placed in the canals. About 2 months later, the calcium hydroxide is replaced with gutta-percha and sealer. The reason RCT is started 2 weeks after the transplantation is that earlier RCT may affect the attachment around the transplanted tooth and obturation material may damage the periodontal ligament. The utilization of calcium hydroxide prior to the final obturation presents a twofold advantage, firstly: if the tooth has not yet completed its formation, calcium hydroxide can facilitate apical closure. Secondly, calcium hydroxide serves as an excellent antiseptic, safeguarding the root canal system free from

bacterial contamination during the crucial phase of healing (24). Root canal treatment performed extra orally at the time of transplantation is both time- and cost-effective. However, there is the risk of damage to the periodontal ligament during the procedure, so extraoral RCT is not recommended unless the periodontal ligament can be kept intact during the procedure, which is very uncertain. Healing of the pulp is expected with transplanted developing teeth. Closure of the apex and positive response to electric pulp tests are expected. The roots should continue to develop. The pulp should be monitored for healing with transplanted teeth at developmental stage 6. Root canal treatment should be started immediately if inflammatory root resorption is suspected, or if irreversible pulpitis is diagnosed. Once closure of the apex with hard tissue after apexification is confirmed, obturation with sealer and gutta-percha is performed (25,44,57).

### 9.17 The natural movement of transplanted teeth

After removal of the splint, the transplanted tooth should be allowed to settle into its new position naturally; however, it is advisable to check for and adjust any developing occlusal interference continually. This will ensure that periodontal ligament attachment and the bony repair proceed properly. During the natural movement and settling of the transplanted tooth, the whole arch will align functionally, providing normal proximal contacts in most instances (1,3,45).

### 9.18 Orthodontic movement of transplanted teeth

When the position or the angulation of the transplanted tooth in the arch is not ideal, or when orthodontic treatment has been planned prior to the surgery, the treatment should be initiated at the appropriate time. Not only the transplanted tooth position but also the height of the alveolar bone can be changed by orthodontic movement (39). It is better to start the orthodontic movement after complete healing of the periodontal ligament around the transplanted tooth (usually about 8 weeks) but before complete healing of the alveolar bone. Extrusive orthodontic movement can be started 1 month after the procedure. The movement of the roots out of the alveolar bone can prevent early ankylosis (42-44).

### 9.19 Restorative treatment of transplanted teeth

In an ideal situation, when a developing third molar is transplanted to another site in the arch, restorative treatment does not become necessary, the pulp heals and no root canal therapy is needed. In situations where ideal conditions are not present, some aspects of restorative dentistry may be required, such as restoration of an access cavity after root canal treatment, the improvement of interproximal contact, or recontouring the crown (e.g., when a premolar is used as an anterior tooth). Transplanted teeth are natural teeth and, all types of restorative treatments can be applied. However, composite resin restorations are the first choice of material considering the cost of treatment and preservation of esthetics of enamel. Bleaching can be performed before restorative treatment on a root canal-treated anterior transplanted tooth. If it requires extensive recontouring, an all-ceramic restoration can be fabricated. In the case of developing teeth, any preparation should be finished in enamel, or prepared teeth should be restored as soon as possible if the preparation is finished in dentin, because if the bacterial infection progresses deep in the dentin, lesions of endodontic origin (LEO) tend to develop around transplanted teeth with closed pulps, a condition that is difficult to treat (1,3,39,44).

## 10. Post-surgical requirements

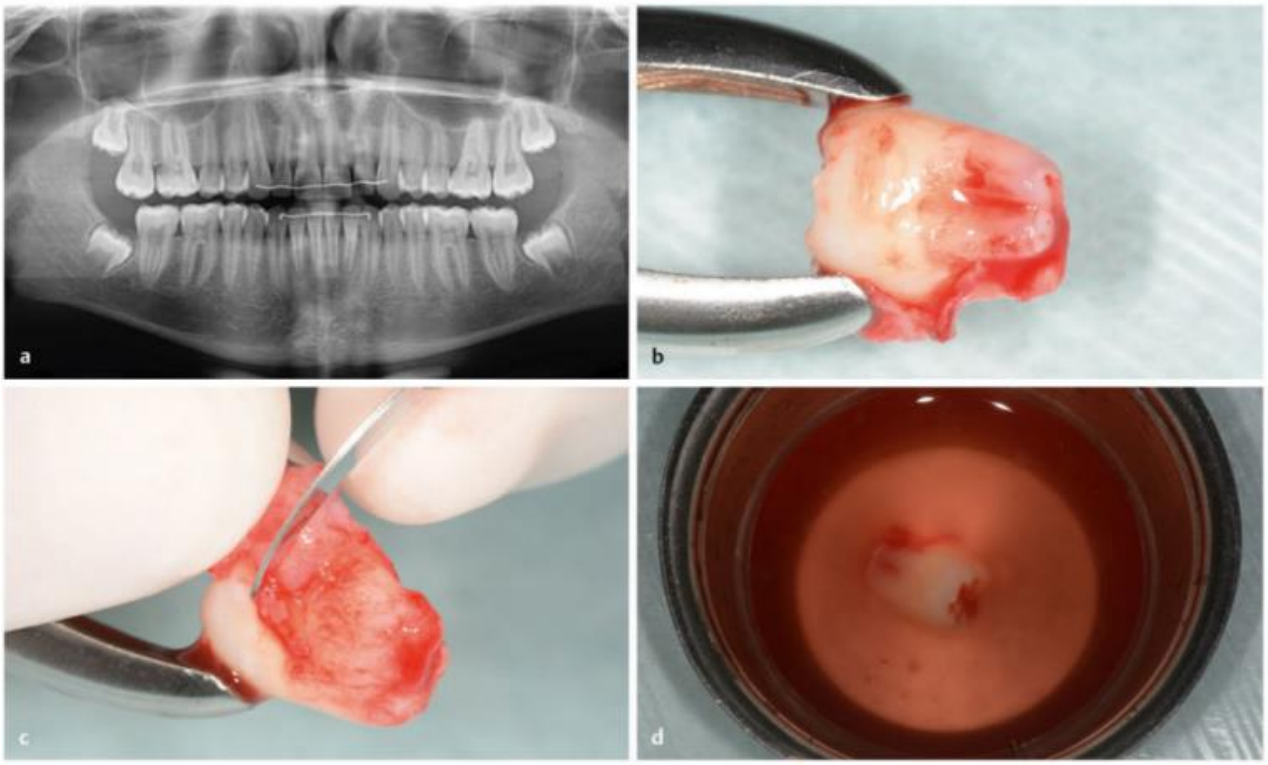
The post-surgical requirements include among others, the stabilization of the tooth after transplantation. There are several methods of splinting, that have been proposed post-surgically. The fixation method of the splint is generally determined by the initial stability of the transplant. If the transplanted tooth fits well into the prepared socket and between the adjacent teeth, only a mattress suture required. A recent evidence-based appraisal of the literature indicated that the type of splint was not a significant factor in healing (56). Despite the lack of evidence-based guidelines with respect to the duration of splinting, it has been hypothesized that prolonged splinting duration and rigid splinting materials may contribute to the development of ankylosis and, therefore should be avoided (27,54,59). It is also recommended that the transplant must be taken out of traumatic occlusion post-surgery.

Regular follow-up protocols after tooth transplantation are necessary for clinical and radiographic monitoring. It consists of a diagnostic post-operative radiograph and constant inspection of the pupal and periodontal healing. Transplanted teeth should be monitored on a schedule: at 1, 2, 3, 6, and 12 months then yearly (43). The evidence of pulpal healing in developing teeth is continued root formation and pulp space obliteration, while the presents of

perriradicular lesions or resorption indicate a lack of pulpal healing. Gingival healing can be improved by meticulous home hygiene by the patient.

Pulp testing is a post-surgical requirement to check the viability of the transplant. Immature transplants usually regain their sensibility within 6-12 months after transplantation in 90% of cases (24,25).

Clinical Case example: (62)




a) A panoramic x-ray of a 17-year-old patient with cervical resorption of tooth 16. Planned therapy: removal of tooth 16 and transplantation of tooth 18 to region 16.
b) Graft harvested, tooth 18 with >50% advanced root growth and wide, open apical foramen.
c) Excessive portions of the dental sac are sharply separated with the scalpel, but a narrow strip of soft tissue remains at the tooth neck to facilitate subsequent dentogingival closure.

d) The tooth to be transplanted is stored in a cell culture medium with the addition of antibiotics and steroids.

e) Clinical situation after extraction of tooth 16 and enamel etching of the neighboring teeth to splint tooth 18 in its new position.
f) The transplant 18 is attached to the neighboring teeth in the recipient region using a TTs splint.
g) Postoperative control x-ray: transplanted tooth 18 in region 16
h) Clinical situation one year after transplantation of tooth 18 in region 16: the tooth is vital and shows no signs of ankylosis

i) Occlusal view 12 months after transplantation: tooth 18 fits very well into the existing row of teeth in terms of shape and color.
j) Lateral view in habitual occlusion.
k) Clinical picture 2 years after transplantation.
l) Tooth x-ray 2 years after transplantation: there is no evidence of root resorption. Root growth is complete, which can be evaluated as a vital pulp reaction.

# 11. Complications of tooth autotransplantation

## 11.1 Intra-operative complications

General intra-operative surgical complications include hemorrhages, fractures of the bone and pain.

11.2 Post-operative complications

Root resorption occurs when a donor tooth with partial or total lack of vital periodontal ligament is transplanted. Resorption is categorized into three types: inflammatory resorption, replacement resorption, and surface resorption. Unlike replacement resorption, inflammatory resorption can be arrested by root canal therapy if performed early. After root canal therapy, the granulation tissue is replaced with periodontal ligament tissue and healing by new attachment occurs. Inflammatory resorption usually occurs 3 to 4 weeks after the procedure, whereas replacement resorption (ankylosis) takes 3 or 4 months to 1 year to become evident. Thus, transplants must be followed for at least 1 year to be considered successful (22). Further complications could be the necrosis of the pulp, the lack of or compromised periodontal healing and the reduction of the final root length (54,66). Usually, all postoperative complications lead to transplanted tooth loss.

# 12. How successful is autotransplantation of teeth?

The success of autotransplanted teeth is evaluated based on complete healing, followed by the function and maintenance of a healthy tooth alveolar process.
The survival rate is defined as the persistence of the tooth transplanted despite possible compromised aesthetics, function or not complete development of tooth roots (28).

<u>Criteria for success of autotransplantation in incomplete development of a transplanted tooth:</u>
Radiographic examination:
-alveolar bone healing
-the presence of lamina dura
-The Periodontal Ligament space width is normal around the transplanted tooth
-No evidence of progressive inflammatory root resorption
-No disturbance in root development

Clinical examination:
-tooth function and mobility normal
-Gingival healing and no indication of inflammation or marginal attachment loss
-Healing of dental pulp and revascularization
-No discomfort for the patient

-Normal percussion sound

Criteria for success in completely developed transplanted teeth:

The requirements are the same as for incompletely developed transplanted teeth, with the exception that pulp is not expected to revascularize and root canal treatment is always indicated (39,54,61).

## 13. Analysis of Clinical Results

Numerous studies are focusing on the success of tooth autotransplantation. However, the comparability of the studies is often not given due to different surgical techniques, including types of teeth, performed drug therapies, or varying criteria for success and failure.

Table 1. Success and survival reported for autotransplantation results given for mature/immature teeth, respectively.

| | **Number of teeth** | **Follow-up** | **Success rate** | **Survival rate** |
|---|---|---|---|---|
| **Czochrowska et al. 2002** | **33** | **17-41 years (mean 26,4)** | **79%** | **90%** |
| **Mitsuhiro Tsukiboshi et al. 2013** | **129** | | **85,3%** | **94,6%** |
| **Diaz et al. 2014** | **26** | **2-6 years** | **83,3%** | **97,2%** |
| **Stange et al. 2016** | **15** | **12,3 years** | **-** | **100%** |
| **Kafourou et al. 2017** | **89** | **13,2 years** | **-** | **94,4%** |

The meta-analysis by Almpani et al. showed that the status of root development has a significant influence on the success of tooth transplants. A lower risk of failure was found for teeth with an open apex than teeth with a closed apical foramen. Atala-Acevedo et al. came to similar conclusions in their systematic review and meta-analysis of autotransplantation of teeth with an open apex. They reported a survival rate of 98% and a success rate of 89% after a follow-up of more than 6 years (63). The current study also showed that premolars have a lower risk of failure than transplanted molars. Also, in the retrospective analysis by Ronchetti et al., premolar transplants were significantly more successful than transplanted molars (n=75 transplanted

teeth), in addition, it could be shown that the experience of the surgeon has a significant influence on the success of the surgery (64). On the other hand, the study of Schuetz et al., reported a success rate of 94% in wisdom tooth transplantation after an average of 26 months (n=57) (65).

## 14. Future prospects

The use of computer-guided rapid prototyping of a three-dimensional replica of the donor tooth is a new suggested technological advancement for tooth autotransplantation.

In conventional autotransplantation, the extracted donor teeth are used as a template for the preparation of the new socket at the recipient site. This needs the manipulation and several fitting attempts of the extracted donor tooth to achieve optimal adaptability between the root surface of the transplanted donor tooth and the recipient bone socket (61). Each fitting attempt carries an increased risk of trauma to the periodontal ligament and prolongs the extra-oral time (40). The risk of damaging the donor tooth is reduced in modern autotransplantation techniques using of a preoperatively designed surgical template instead the donor tooth (66). This replica can be made based on a preoperative cone beam computed tomography (CBCT) of the donor tooth. The replica serves as an orientation aid during the surgical procedure and enables an uncomplicated and quick autotransplantation procedure (67-70).

Advantages:

1. The extra-alveolar time of the donor tooth is minimized
2. The size and shape of the neo-alveolus are accurately replicated in the 3D model, therefore several fitting attempts during the placement of donor tooth can be avoided. This allows the periodontal ligament cells of the donor cells to be better preserved.
3. During the autotransplantation procedure, the use of replica increases the simplicity and control.

## 15. Conclusion

Tooth autotransplantation is a surgical method that is suitable for certain clinical situations. It involves transplanting teeth to distant or opposite sides of the same dental arch or to the opposite jaw, thereby replacing missing teeth and restoring a normal alveolar process. This

technique can also stimulate bone growth. Recent studies show that success and survival rates have improved, but they depend on various factors such as the donor tooth, recipient site, and surgical technique. Tooth autotransplantation is beneficial for pediatric patients and adolescents when other tooth restoration options, such as implant placement, are still contraindicated, because of unfinished growth of the jaws. Open apex donor teeth are the preferred option due to lower complication rates compared to closed apex donor teeth. However, successful outcomes require a thorough understanding of the factors that influence long-term success rates. When performed properly, tooth autotransplantation can serve as a viable treatment option in clinical practice.

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