

Inga Mollen, Thomas Bernhart, Andreas Filippi

Transplantation of teeth after traumatic tooth loss



**Inga Mollen,
Dr med dent**

Center of Dental Traumatology, Department of Oral Surgery, Oral Radiology and Oral Medicine, School of Dental Medicine, University of Basel, Basel, Switzerland

**Thomas Bernhart,
Prof Dr med dent**

Department of Oral Surgery, School of Dental Medicine, University of Vienna, Vienna, Austria

**Andreas Filippi,
Prof Dr med dent**

Center of Dental Traumatology, Department of Oral Surgery, Oral Radiology and Oral Medicine, School of Dental Medicine, University of Basel, Basel, Switzerland

Correspondence to:

Inga Mollen
Center of Dental Traumatology, Department of Oral Surgery, Oral Radiology and Oral Medicine, School of Dental Medicine, University of Basel, Hebelstrasse 3 CH-4056 Basel, Switzerland
Email: Inga.mollen@unibas.ch

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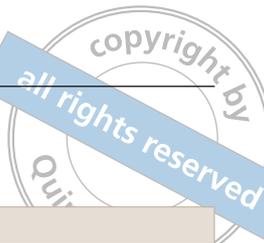
Trauma to the anterior teeth is a frequent reason for tooth loss in children and adolescents. The transplantation of teeth is an established and biological therapy for replacing missing anterior teeth in these age groups. Premolars and primary canines are suitable for replacing anterior teeth in the maxilla due to their root anatomy and the corresponding emergence profile. This article gives an overview on the indications of tooth transplantation in the anterior maxilla, the surgical procedure and a short survey of the developments in current literature.

■ Introduction

The transplantation of teeth is an established biological treatment option after tooth loss, for example through traumas or agenesis of permanent teeth particular in children and adolescents. Because there are more common procedures, the dentist may in many cases not consider tooth transplantation immediately. There is a variety of different therapies to the problem of tooth loss; their selection being dependent on patient related factors as age, compliance and individual preferences. Gaps can be closed by orthodontic treatment, by placing dental implants or using fixed prosthesis (resin-bonded or conventional). Especially in children and young adults the element of growth should be kept in mind, which can influence lasting treatment success. In this age group the replacement of teeth should not interfere with jaw growth. Therefore, tooth transplantation may represent the therapy of choice, which however might be limited by the availability of an appropriate donor site.

■ Indications

There are various reasons for tooth loss in children and adolescents (Table 1). Trauma is one of the most common reasons for missing teeth in the anterior maxilla. If central or lateral incisors are lost due to accidents, an extensive dental treatment and attempts to preserve that tooth may have taken place. In these cases, the main objective will be the regeneration of hard and soft tissue, which was previously lost due to trauma. The transplantation of autologous teeth, unlike a dental implant, offers the potential of generating new bone formation¹. Although sometimes the lack of hard tissue requires a more apical or oral positioning of the donor tooth in the recipient site, this location will be corrected by orthodontic treatment after a new formation of periodontal ligament. Because of their anatomical characteristics, premolars of the mandible or maxilla or even primary canines are suited for replacement of maxillary incisors. Which tooth complies with the requirements for transplantation best depends on the patients' age and the stage of root development. In children between the ages of 10 to 14 years, first and

**Table 1** Causes for tooth loss or common locations of tooth agenesis³.

Disease	Trauma	Agenesis
Destruction by caries or apical periodontitis	Avulsion with impossible replantation	Maxillary or mandibular premolar
Localised juvenile periodontal disease	Post-traumatic resorption	Lateral maxillary incisor
Endodontic complication	Vertical root fracture	Other
Unsuccessful combined orthodontic – surgical therapy in retained maxillary canine	Ankylosis	

**Fig 1** Progressive infraposition in a 25-year-old female patient 7 years after implant placement.

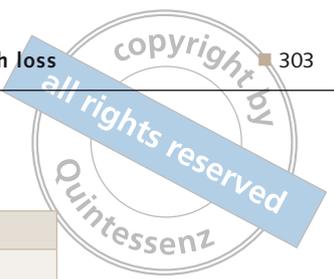
second premolars have usually reached 50 to 75% of root development and offer good prognosis for transplantation. In patients younger than 10 years with loss of permanent incisors, primary canines may represent an alternative if premolars are not available. This treatment can only be performed when there are no pronounced signs of physiologic root resorption. Compared to transplantation of permanent teeth, revascularisation cannot be expected. Therefore, a titanium post is recommended for retrograde cementation into the root canal of primary canines. This technique is additionally seen as an extension of the root for a better crown-to-root-ratio.

In children and adolescents, the placement of dental implants to replace missing teeth is contraindicated in growing parts of the maxilla and mandible. Especially in the anterior region of the maxilla, implants represent a major risk for aesthetic failure and complications in young people (≤ 30 years) (Fig 1). Jemt et al² stated that movements of teeth could be seen in the anterior maxilla adjacent to single implants. Females with a long face anatomy show the highest risk for tooth movements next to implants. This finding may be explained by a significant increase of anterior face height and mandibular clockwise rotation.

■ Presurgical diagnostics

A successful transplantation depends on exact analysis and individual planning prior to surgery. It is a multidisciplinary approach including orthodontists, oral surgeons and dentists. The patient should show good physical conditions. Severe diseases, diseases with compromised wound healing or blood-clotting disorders are contraindications for tooth transplantation. The patient's compliance should be sufficient to perform the surgical intervention in local anaesthesia. In case of follow-up interventions (e.g. endodontic treatment, failure of the transplant, orthodontic treatment), sufficient cooperation for an outpatient treatment is necessary. Precise analysis of the available space in the recipient site matching the crown width of the donor tooth has to be performed before transplantation. This has to be carried out clinically and radiologically. In the case of retained teeth or unclear bone conditions seen in two-dimensional radiographs, cone beam computed tomography (CBCT) can be valuable. The interocclusal space and the jaw relation have to be regarded. If the gap for transplantation is not sufficient, space needs to be created through orthodontic treatment. If the space matches nearly the diameter of the transplant, a tooth stripping can be considered within the meaning of a gentle reduction in tooth enamel of about 0.5 mm. Dentine exposure should be strictly avoided, because of the high risk of invasion of microorganisms resulting in pulp necrosis.

The transplant should also possess a vital periodontal ligament (PDL). A better prognosis for the transplant can be seen with teeth that show an open apical foramen of about 2 mm diameter. The root should have reached a length of approximately 50 to 75%⁴. Elective treatments like tooth transplantations require a careful and detailed elucidation. The patient or the parents should sign a detailed informed consent form including risks, po-

**Table 2** Choice of transplants and their possible destination with the corresponding SAC-classification.

Transplant	Possible location for transplantation	SAC-classification
Maxillary third molar	Maxillary molars (same side) Mandibular premolars (Maxillary molar opposite side)	Straightforward Advanced Complex
Mandibular third molar	Mandibular molars (same side, opposite sides) Mandibular premolars (maybe 90 degree rotation) Maxillary molars (maybe 90 degree rotation)	Straightforward Advanced Complex
Maxillary primary canine	Maxillary incisor (maybe 180 degree rotation)	Complex
Maxillary premolars	Other premolars Maxillary incisors (maybe 90 degree rotation)	Straightforward Advanced-Complex
Mandibular premolars	Other premolars Maxillary incisors	Straightforward Advanced-Complex

tential subsequent treatments and possible failure of the transplant.

■ SAC-classification

In oral implantology the SAC-classification developed by the ITI (International Team for Implantology) in 2007 provides guidelines for the clinicians to categorise implant cases with different levels of complexity: Straightforward (S), Advanced (A), and Complex (C)⁵. In analogy, according to Filippi this classification can also be used in tooth transplantation (Table 2). A 'Straightforward' example is, for instance, a transplantation of a maxillary third molar with immature roots within the same quadrant into the position of a first molar with sufficient bone volume in all three dimensions. The category 'Advanced' includes transplantation of maxillary third molars into the place of a mandibular premolar as well as the placement of a maxillary or mandibular premolar to replace a central maxillary incisor, if there is sufficient bone and no occlusal interferences. 'Complex' cases include transplants of a premolar into the position of a central maxillary incisor with interocclusal interferences and/or with bone or tissue deficiency, of a third molar into another toothed quadrant than the donor site, primary canine transplantation (Figs 2 to 5), transplantation of teeth to replace a lateral incisor and multiple side-by-side transplantations.

■ Surgery

Tooth transplantation is a surgical therapy, which is mostly done in young patients. The maximum dose of local anaesthetics needs to be considered by taking the patient's body weight into account. There are no reports about adrenalin-containing local anaesthetics showing negative side effects on success rate of tooth transplantation.

An antibiotic therapy (e.g. amoxicillin and clavulanic acid) starting prior to surgery should be discussed on an individual basis. Depending on individual case-related circumstances, the first steps of the surgical treatment are a gentle removal of the tooth that is not preservable as well as removal of the transplant. A flapless approach including a sharp incision with a microsurgical scalpel (no periosteotomy) should be carried out. This procedure allows a fast healing of the gingival tissue supported by primary connection of the blood vessels. To prevent damage to the recipient region, there are tissue preserving extraction systems available (e.g. Benex, Luzern, Switzerland; Zalex, Hohenwarthe, Germany) that offer a gentle removal. In erupted teeth with a single root, a rotational extraction technique may preserve the alveolar bone better than tooth removal under extensive orofacial movements. Retained or impacted transplants should be as carefully removed as possible. It has to be ensured that the PDL is not damaged during surgery or during osteotomy. In selected cases, piezo-surgery may be advisable.



Fig 2 Case 1: 8-year-old male patient with a vertical crown- and root fracture of tooth 11 due to trauma.



Fig 3 Case 1: Two weeks after removal of tooth 11 and transplantation of the left primary canine (tooth 63).



Fig 4 Case 1: Radiograph taken 4 months after transplantation (left side) and nearly 6 years following transplantation of tooth 63 into the position of the right central incisor.



Fig 5 Case 1: Clinical situation 8 years after transplantation and reconstruction with composite of the primary canine 63 into the position of the right central incisor.

Special forceps with diamond grit reduce flipping of the tooth during removal.

The removed transplant should be stored immediately in a moist and physiologic medium to maintain the metabolism of vital cementoblasts and fibroblasts on the root surface. These cells are necessary in order to avoid ankylosis of the transplant. Physiological depositories are nutrient cell culture media (e.g. Dentosafe, Zahnrettungsbox, Medice, Iserlohn, Germany; SOS Zahnbox, Zahnrettungsbox, miradent, Duisburg, Germany) to which 1 mg doxycycline and 1 mg dexamethasone (no resorb, Medcem, Weinfelden, Switzerland) can be added⁶. Nutrient cell culture media may help to flush out toxic breakdown products of tissue and bacteria⁷. The above-mentioned approach of applying nutrient cell culture medium with additional doxycycline can help to improve incorporation of vital tissue through an open apical foramen into the pulp chamber. This procedure can duplicate the chance of revascularisation of the pulp⁸.

If there has been damage to the root surface of the transplant during surgery, a local therapy with corticosteroids (no resorb) can be applied. The osteoclast activity, which usually is responsible for root resorption, can be reduced by this approach⁹. The coronal part of the transplant should be inspected for dentine exposition, if a surgical removal with osteotomy was necessary. Exposed dentinal tubuli offer an entry for microorganisms, which can rapidly lead to pulp necrosis and apical periodontitis in transplanted teeth.

If the recipient site has already healed, there will be the need for preparing a root corresponding pseudo alveolar socket. This can be performed using root-shaped implant burs or surgical round burs corresponding in length and width to the root of the donor tooth. In distinction to implant preparation, this preparation should be wider in diameter and length than the root of the transplant. There should be a lateral distance about 0.5 mm to 1 mm around the transplant towards the alveolar socket.



Fig 6 Case 2: Clinical situation immediately after surgery and fixation of the transplant (tooth 44) with a titanium trauma splint (TTS).



Fig 7 Case 2: The clinical situation 6 weeks following transplantation of tooth 44 and removal of the TTS shows a bland dento-gingival healing.



Fig 8 Case 2: Clinical situation approximately 2 years following transplantation with a fixed orthodontic appliance in situ. The transplant was reconstructed using composite material. The two lateral incisors are missing due to agenesis.



Fig 9 Case 2: Clinical situation 7 years following transplantation of tooth 44 to replace the right central incisor, successful orthodontic treatment and composite reconstruction.

Underneath the root apex, a 2 mm-distance should be maintained towards the alveolar bone. The transplanted tooth should be positioned in the socket in consideration of the optimal adaption of gingival tissue. To achieve a tight dento-gingival seal around the transplant, remnants of the dental follicle can be left around it. Also the emergence profile has to be evaluated during this positioning. It should be considered that sometimes an improved position could be achieved through rotating the transplant of about 90 or 180 degrees. The terminal occlusion should be inspected after positioning the tooth into the alveolar socket. The transplanted tooth should be set in slight occlusal contact to the antagonistic teeth or in minimal inferior position. A flexible metallic splint (e.g. TTS; Medartis, Basel, Switzerland) is fixed adhesively with phosphoric acid gel, bonding and composite to the neighbouring teeth for 2 to 6 weeks (Figs 6 to 9). The duration of splinting depends on the clinical parameters (percussion sound, periosteal values). The functional occlusal impulse on trans-

plants supports the periodontal healing¹⁰. A rigid splint increases the risk for ankylosis of the tooth and can influence the revascularisation of pulp tissue negatively¹¹. The root length in autotransplants with a rigid fixation is significantly negatively influenced compared to suture splinting. The titanium trauma splint (TTS) offers an adequate intraoral fixation, which allows physiologic tooth mobility. The design of TTS allows a simple application and removal¹². Crossing sutures to fix a transplant should only be used when primary stability is sufficient. This technique has been often used for transplantation of premolars, as their crown shape permits a good fixation by crossing sutures.

Emdogain (Straumann, Basel, Switzerland), which is successfully used during regenerative periodontal therapy, can replace localised acellular cementum¹³. There is little scientific evidence about the application of Emdogain in replanted or transplanted teeth, due to lack of randomised controlled trials and clinical controlled trials¹⁴. In cases of tooth transplantation



Fig 10 Case 2: 10-year-old male patient; series of radiographs: (a) Initial situation after loss of tooth 11 due to avulsion; (b) Situation after transplantation of the donor tooth 44 into the position of the right central incisor (c) nearly 6 years following transplantation; pulp obliteration is a sign of revascularisation of the pulp tissue.

with traumatic removal of the transplant or damage to the root surface, Emdogain might improve the outcome of the transplantation¹. The root surface must not be conditioned with EDTA.

■ Recall and prognosis

Paracetamol or non-steroidal anti-inflammatory drugs (NSAIDs) are advisable for approximately a few days after surgery. A systemic antibiotic treatment shows no significant influence on the outcome of tooth transplantation and is therefore not mandatory⁴. During postsurgical recall, the patient should maintain ideal oral hygiene as plaque accumulation degrades periodontal healing. Subsidiary chemical plaque control should be performed with a 0.2% chlorhexidine mouth rinse. Sutures can be removed about 7 days after surgery. Immature transplanted teeth especially should be evaluated regularly during the first postsurgical months.

Periotest values can demonstrate the development of periodontal healing and bone formation. These values can be compared to those of the neighbouring dentition. A clear sign for ankylosis are decreasing periotest values of 0 or less. Radiographs to control root development or signs for resorption, clinical evaluation and sound of percussion are recommended annually after a successful healing process. Evaluation of pulp regeneration takes more time than periodontal healing. Approximately after 3 to 6 months, there might be a positive pulp sensitivity test or radiographic signs of further root development that demonstrates successful revascularisation. In the literature, pulp obliteration after transplanta-

tion of teeth is generally acknowledged as a treatment success^{15,16}. Pulp obliteration can also be seen 3 to 6 months after transplantation (Fig 10)¹. In case signs of pulp necrosis become apparent, root canal treatment should be initiated immediately. In immature teeth with incomplete formed roots, calcium hydroxide should be applied as an intracanal dressing to enable apexification. Endodontic complications show better response to treatment than periodontal infections. For the comparison of literature, it is important to define and to clarify the terms of survival and success rate. The survival rate implies that the transplant is still *in situ*, whether or not signs of complications like ankylosis, apical periodontitis or root resorption are present. In contrast, the success rate excludes transplanted teeth with periodontal or endodontic complications. There are several heterogeneous publications of success and survival of transplanted teeth differing in the kind of tooth as well as the area of reception and different fixation techniques.

Mendoza et al reported a success rate of 80% after a 1-year-follow-up of transplantation of premolars to substitute maxillary central incisors. Teeth with two-thirds' root development showed the best results. Additionally, a positive correlation between complete pulp obliteration and further root formation and viability of the transplanted tooth was described by Mendoza et al¹⁷. Factors affecting the success of transplantation of teeth with complete root formation were examined by Sugai et al¹⁸. They found an average 5-year-survival rate of 84%. It was stated that patient age above 40 years, molar teeth as donor, probing pocket depth of 4 mm or more, root canal treatment of the graft, teeth with more

than one root and suture fixation were significantly related with unsuccessful results of transplantation. The main reasons for transplant failure were insufficient initial healing and replacement root resorption associated with periodontal inflammation. Other possible risk factors published by Yoshino et al were a reduced dentition of 25 or less teeth after surgical intervention, as well as tooth loss due to periodontal disease next to the transplanted tooth. According to their findings, in most cases the circumstance of adjacent tooth loss led to further attachment loss at the transplant site¹⁹. Kim et al²⁰ found a failure rate of 4.5% in short to intermediate observation period. Another study conducted by Czochrowska et al¹⁶ who analysed mainly premolars as donor teeth, showed a long-term transplant survival rate of 90% and a success rate of 79%.

■ Conclusion

Overall, tooth transplantation offers the possibility to replace a missing tooth in a biological way. Especially in cases of traumatic tooth loss in children and adolescent during jaw growth, it may represent a good alternative for prosthodontics or orthodontic therapy. A thorough diagnostic and treatment planning is essential for treatment success.

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