

Long term survival of mature autotransplanted teeth: A retrospective single center analysis

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ABSTRACT

Objective: The replacement of an irretrievably compromised tooth requires an implant rehabilitation or a traditional fixed partial denture. In well-selected cases, a further therapeutic possibility is represented by tooth autotransplantation. Although dental transplants are poorly understood and practiced, the international literature agrees that it is considered the first choice when applicable. The advantages of this technique are numerous: use of an autologous element, maintenance of tissue trophism, aesthetic and functional restoration, costs reduction.

Although autotransplantation is often performed with immature teeth, even mature teeth with fully formed apex can be used as donors. The aim of the present work was to analyze consecutive cases of completely formed donor teeth autotransplantations performed from 2005 to 2011 in 21 patients for evaluating the survival and success rate.

Materials and methods: The medical records of patients who underwent transplantation in a specialized center in Rimini (Italy) from 2005 to 2011 were checked. Only transplants of mature donor molars were considered. Patients were called up to evaluate the survival rate and success rate.

Results: The mean age at the time of the surgery was $33,6 \pm 7,4$; mean follow up was $11,9 \text{ years} \pm 1,9$.

Success rate at the time of latest recall visit was 80 % and survival 95 % of the analyzed cases.

Conclusions: The survival and success rate are in complete agreement with the most recent literature and confirm that the technique of autotransplantation is reliable when indications and protocols are rigidly followed, also using mature teeth as donors.

1. Introduction

The transplantation of a tooth from a site to the receiving socket of the same patient, named autotransplantation, represents nowadays a well-documented technique that should be considered in the treatment plan of hopeless single teeth, as therapeutic alternative of prosthetic implant or conventional rehabilitation [1]. Tsukiboshi divided tooth transplantation in three types [1]: *intra-alveolar transplantation* applied in the repositioning of the same tooth within its alveolus (uprighting, rotating, extruding), *conventional replantation* used for the replacement of a lost or missing tooth, or finally, *intentional replantation* applied for the extraoral endodontic treatment of a tooth that is immediately repositioned inside its primitive alveolus [2]. Other variables concerning this procedure regard the recipient site (fresh extraction socket, delayed extraction socket or artificial alveolus) and the root development of the

transplanted tooth [3]. These variables affect the clinical steps of the procedure and the predictability together with the possible complications encountered because the treatment [4,5]. Despite the encouraging survival rate of dental implants both in post-extractive [6–8], pristine [9] and regenerated bone [10], clinicians should keep in mind the prevalence of peri-implant mucositis [11,12] and peri-implantitis [13,14] that may affect long-term success rate of implant-based rehabilitation. Recent observational studies and systematic reviews show good predictability of autogenous tooth transplantation, comparable to dental implant treatment [4,5,15]. Moreover, some limitations reduce the broad spectrum application of implant rehabilitations such as the age (skeletal development) of the patient [16], the need for orthodontic treatment [17] and the disposable income [18–20] where auto-transplant option appears more favorable. Conversely, however, donor tooth should be available in the oral cavity and certain conditions have

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to be fulfilled to be transplanted. The most common indication for autotransplantation is the replacement of a single tooth lost for trauma [21], restorative or endodontic issues, periodontal or periapical inflammation. In addition, tooth transplantation may also be used to treat congenitally edentulous missing teeth or pre-existing tooth gaps [22]. Importantly the main advantage is the autologous source of the grafted organ that brings several improvements such as a vital periodontal ligament, adaptatively eruption, preservation of bone volume, chance to move the tooth according to orthodontic treatment [1,17,23]. These peculiarities are related to the presence of a vital periodontal ligament which necrosis may bring otherwise complications that affect this procedure: these are represented by ankylosis, external root resorption, periodontal attachment loss and mobility [1,5,15].

Tooth autotransplantation, often associated with orthodontics in the multidisciplinary approach to the growing patient, is well documented with long-term follow-up demonstrating its effectiveness [24]. Moreover, in the growing patient, the use of developing teeth as donors allows to obtain a transplanted tooth that also maintains vitality. Mature tooth transplantation is less documented in the long term. In this case, the transplanted tooth must be endodontically treated since the vitality is not maintainable, therefore it is recommended to perform a root canal therapy within a short time after the transplant [1]. Alternative endodontic treatments have also been hypothesized in the mature tooth, such as amputation of the apex with the aim of revascularizing the pulp [25] or retrograde intraoperative treatment of the tooth to be transplanted, without subsequent endodontic treatment [26]. Regardless of the endodontic approach, the evaluation of the success of the mature transplanted tooth cannot consider the maintenance of vitality as the developing tooth.

Since long-term predictability should represent the final goal of such treatments, the aim of this retrospective study is to report the success and survival rate of autotransplanted teeth with complete root formation up to fifteen years of follow up, treated from the same clinician.

2. Materials and methods

Medical charts of a single center located in Rimini (Italy) specialized in dental trauma and tooth transplantation were screened for patients treated by the same clinician (LB) from 2005 to 2011 with appropriate follow-up. All of the patients identified and fulfilling the inclusion criteria (Table 1) were invited for a postoperative recall follow-up of the transplanted tooth. During the last recall visit the patients whose chart was retrieved were informed of the study purposes and after obtaining the consent of publishing the clinical data were finally enrolled. Main outcomes of the study were success and survival rate of the transplanted tooth, according to criteria defined elsewhere by Rohof ECM and coworkers [14] that here are briefly reported: survival was defined as tooth presence during the follow-up, with possible root resorption, periodontal defect, ankylosis, that however remains functional (Fig. 1). Success was defined as the presence of the tooth in the mouth without ankylosis or inflammatory root resorption, without symptoms and with normal mobility (Fig. 2). Secondary outcome was the incidence of biological complications. Inclusion criteria (Table 1) were administered before final enrollment of the cohort in the analysis: molar transplanted tooth, complete root formation and closed apex of the transplanted tooth (Moorrees stage 13 [27]), fresh recipient socket, accurate description of the procedure, complications and presence of preoperative and postoperative periapical radiographs during time of follow-up. Single-rooted transplanted teeth and transplantation due to traumas in frontal areas were excluded from the analysis in order to highlight only conventional autotransplantation treatments, excluding intentional replantation and intra-alveolar autotransplantation (according to Tsukiboshi1). Incomplete root formation of the donor tooth represented also an exclusion criterion. According to the medical chart the surgical procedure was similarly performed to all the patients as here reported.

After radiological examination with OPG and/or periapical radiograph of the donor and recipient site, administration of 2 g of Amoxicillin 1 h preoperatively and twice a day for the six day after surgery [28], atraumatic extraction of the recipient tooth was conducted, together with the extraction of the donor tooth. The interventions were performed under local anesthesia. Only forceps and elevators have been used, directly to the crown and never to the root surface in order to preserve the vitality of the periodontal ligament. After extracting the compromised tooth, delicate debridement was conducted in the receiving socket with saline solution 0,9% together with removal of granulation tissue, whether present. The donor tooth has been extracted similarly and fitting test with the recipient bed followed in the fastest way to preserve periodontal ligament vitality. If coronal misfit was recorded, enamel crownplasty has been performed with diamond burs. If alveolus misfit was recorded, minimal ostectomy has been conducted to allow the fitting in the recipient site, with common surgical and implant burs according to the dimensions of the donor tooth. During surgical procedures, the donor tooth was kept into sterile saline solution 0,9% to preserve periodontal vitality. After seating the tooth in the receiving socket, non-resorbable sutures were applied [29,30] to the interdental papilla and occlusal check was thoroughly carried out, since the tooth was immediately loaded under physiological occlusal forces with the opposite teeth. Subsequently, the transplanted tooth has been splinted to the adjacent, with steel braided wire fixed with cured composite; splinting was kept *in situ* for two weeks. Sutures were removed after 5 days and root canal treatment has been performed the same day of splinting removal (after removing). Follow up visit consisted in three months recall program for the first year and six months interval for the following 2 years; then the recall was annual. During every control a periapical radiograph was executed and tooth mobility and periodontal probing were clinically assessed. Descriptive record of patients' satisfaction was also collected.

Inclusion criteria	Exclusion criteria
Molar donor tooth	Incomplete root formation of the donor tooth
Intentionally transplanted	Transplantation for trauma in frontal areas
Presence of the opposite tooth	
Complete case description	

3. Results

21 patients met the inclusion criteria (Table 1) but one patient (T21) did not show up at the last recall visit, thus it has been removed and not included in the analysis. The detailed descriptions of the patients finally enrolled are displayed in the table. Of the whole sample, 10 were female (50 %) and 10 were male (50 %); mean age at surgery was 33,6 years \pm 7,4. Most of the patients were not smoker (14; 70 %) while 4 (20 %) were mild smoker (less than 10 cigarettes per day) and only two were heavy smoker (10 %) with more than 10 cigarettes per day. Six of the 20 extracted teeth were first lower molars (30 %), 9 (45 %) were second lower molars, 2 (10 %) were upper first molars and 3 (15 %) were upper second molars. Donor teeth were mostly represented by the corresponding wisdom teeth (80 %) for all the cases but T03, T05 and T08 that were substituted by the contralateral wisdom tooth, while T20 with the neighbor tooth (37). Conversely T06 was replaced by the wisdom tooth of the contralateral upper jaw (18–47). Most of the recipient sockets were lower molars (15; 75 %) and most of the donor teeth were lower third molars as well (13; 65 %). One transplanted tooth was extracted after 3 years for acute infection and radiolucency; this tooth never healed correctly since the moment of the surgery, probably due to an alveolitis. Mean follow up of the survived teeth was 11,9 years \pm 1,9 (min 9 – max 15) with and overall success rate at the time of latest recall visit of 80 % and survival of 95 % of the analyzed cases. The reasons for survival (and not success) of four out 19 survived

Table 1
Sample demography.

patient ID	age at surgery	gender	smoking habit	year of extraction	recipient tooth	donor tooth	indication for extraction	reason of choice of transplantation	max time of follow up	outcome	reason for complication
T01	20	F	No smoker	2005	47	48	restorative periodontal	economic	15	survival	Root resorption
T02	28	F	No smoker	2005	47	48	restorative periodontal	Simultaneous indication of third molar extraction	15	success	none
T03	30	F	No smoker	2005	47	38	restorative	economic	15	success	none
T04	30	F	No smoker	2005	46	48	restorative	economic	15	success	none
T05	38	M	No smoker	2007	36	48	restorative	Surgeon's indication	13	success	none
T06	40	M	No smoker	2009	47	18	fracture	Surgeon's indication	11	success	none
T07	36	F	No smoker	2009	17	18	restorative	Simultaneous indication of third molar extraction	11	success	none
T08	36	M	No smoker	2009	27	18	fracture	Simultaneous indication of third molar extraction	11	survival	radiolucency
T09	38	M	Mild smoker	2011	36	38	endodontic	Surgeon's indication	9	success	none
T10	30	F	Mild smoker	2008	36	38	restorative	economic	12	survival	Periodontal defect
T11	31	F	Mild smoker	2009	46	48	periodontal	economic	11	success	none
T12	28	F	No smoker	2006	37	38	restorative	economic	14	success	none
T13	37	M	No smoker	2010	37	38	endodontic	economic	10	success	none
T14	35	M	No smoker	2009	16	18	endodontic	Surgeon's indication	11	success	none
T15	24	M	No smoker	2009	37	38	restorative	Simultaneous indication of third molar extraction	11	success	none
T16	41	F	No smoker	2010	37	38	fracture	Simultaneous indication of third molar extraction	10	success	none
T17	29	M	No smoker	2010	17	18	restorative	Simultaneous indication of third molar extraction	10	success	none
T18	27	M	Heavy smoker	2008	16	18	periodontal	Surgeon's indication	12	success	none
T19	55	F	Mild Smoker	2010	36	37	periodontal	Surgeon's indication	10	survival	radiolucency
T20	39	M	Heavy smoker	2011	47	48	endodontic	Surgeon's indication	3	failure	Acute infection
T21	33	M	No smoker	2010	47	48	endodontic	Simultaneous indication of third molar extraction	7 (last recall)	disappeared	none



Fig. 1. Example of survived transplanted tooth. a) Post transplantation x ray; b) Temporary endodontic medication after the comparison of apical root resorption; c) 10 years follow up. The apical lesion is healed, the apical resorption stopped and the inter-root septum bone is regenerated. This tooth is considered survived, but not a success because of the complication that modified the tooth root.

cases were i) partial external root resorption ii) periradicular radiolucency, iii) periodontal defect. The reasons for the choice of autotransplantation approach were: economic (35 %), the simultaneous indication for wisdom tooth removal (30 %) or the choice of the surgeon (35 %) among the treatment alternatives. Reasons for the recipient tooth removal were restorative (40 %), periodontal (20 %), roots fractures (20 %) or endodontic (20 %). The totality of the sample reached a fully rehabilitation of chewing function after two months, reporting a complete satisfaction of the treatment outcome and choice of approach.

4. Discussion

Indications for tooth autotransplantation include traumatic tooth loss, congenitally missing teeth, replacement of teeth with bad prognosis, or developmental dental anomalies.

Extraction and replacement with a single implant rehabilitation should be considered only for unfavorable prognosis of conservative or surgical alternatives, for up-to-date state of art [31]. In fact the medium-term survival rate of dental implants was established in 96,3% after 5 years of function [32]. Nonetheless the patient should be aware of the difference between success and survival, mostly for the aesthetic zone. However, for several reasons, such as costs as well, tooth autotransplantation should be considered as a treatment option to share with patients. Given actual technical orientation and biologic justification, autotransplantation represents a viable and favorable treatment. The most important and intuitive limitation of this technique is the availability of a donor tooth. It is usually represented by a wisdom tooth but it can be also a second molar in case of first molar substitution. Sometimes the wisdom tooth surgical extraction itself represents a limitation or an increased risk of complications for this procedure [33]. On the other hand however, tooth autotransplantation can be the single option in case of pediatric patients in which dental implants are contraindicated because the developing maxillary jaws. Moreover, the transplantation of a tooth implies also the maintenance of the

proprioception, which is otherwise almost completely lost in case of implants. This aspect may be relevant mostly in childhood. In addition, an autotransplanted tooth retains a vital periodontal ligament, whereby it can be moved orthodontically.

The total treatment cost is usually lower than other treatment plans including implant-based prosthetic rehabilitation, prosthetic restoration, and/or orthodontic space closure [34,35]. Mainkar A. [18] compared the mean costs of the aforementioned treatments reporting that the cost of a tooth autotransplantation represents the 23,5% of the average cost of a single implant rehabilitation according to the American 2016 Dental Fees Survey (1018,67\$ versus 4330,21\$, respectively). The economic aspect was relevant also for our sample, in which represented the 36,8% of the reasons of choice for this approach. Considering the autotransplanted teeth survival rate as determined by a recent meta-analysis of 89.1 % [18] and for comparison, Raghoobar and Vissinck [36] reported a survival rate of 86 % with a 5.2-year mean follow-up, while Choi et al. [37] reported a survival rate of 91.2 % with a 4.4-year mean follow-up, concluding that there are several reasons to take this technique into account. However, despite the body of literature on this topic, the quality of evidence is still considered low, for the methodological limitations that affect the published studies and the systematic reviews based on them [30]. It is relevant that all studies, although with limited scientific methodology, achieve the same result: the autotransplantation is a recommended procedure when applicable. This paper reports, to the authors' knowledge, the longest follow-up of mature autotransplanted teeth cohort. The 95 % survival rate and the 80 % success rate of the 20 cases analyzed confirms again the prognosis of the technique. Even if retrospective, this study shows some interesting methodological aspects such as the single center and operator, the similar treatment protocol, etc. Despite this, the small sample of patients cannot include all the variables affecting this treatment outcomes. One example is the reversible fixation during the first two weeks. According to Almpani [30] the use of rigid fixation is more likely to bring ankylosis, that however, may appear not sooner than two years of follow-up. This aspect is in accordance to the rationale of



Fig. 2. Example of successful tooth transplantation. a) Pre-operative x ray of transplantation of impacted lower third molar in second molar position; b) Post transplantation x ray – before the surgery the first molar was retreated and covered with a metal-ceramic crown; c) 15 years follow up. This is an example of success because the transplanted tooth is perfectly healed without any kind of post-operative complication.

appropriate functional movement of the transplanted teeth during the fixation period that is crucial for a successful periodontal healing. Despite this, in the presented cases, none showed radiographic and clinical signs of ankylosis. However, suture splint or flexible titanium wire with composite splint should be considered, according to more recent evidence that highlights a 3.7 RR in favor to suture splint. The most demonstrated protective factor is represented by the root formation: open apex transplanted teeth are more likely for success than the complete root formed. It was recently reported more than 95 % of success rate for open apex teeth in a dedicated systematic review [4]. Nonetheless another systematic review dedicated to complete root formed teeth showed a 5-years-survival rate of 90 % that is in line with our results. The managing of an incomplete formed root tooth appears to be different: while pulp regeneration is unpredictable for adult teeth, it is otherwise probable for young forming teeth. This aspect implies a mandatory root canal treatment of the former; conversely, root canal treatment may be optional for the latest. Jang and coworkers found 15 min as threshold of extraoral time for intraoperative root canal treatment during transplantation, for better clinical outcomes [38]. Therefore, pre- or post-transplantation endodontic treatment should be considered, for mature teeth.

The small sample does not allow any statistical analysis with the reported variables to highlight any correlation effect. The complications for instance, were limited and did not prevent the function but probably the long term prognosis. We encountered two cases of periradicular radiolucency, one periodontal defect, one external root resorption and we lost a case due to acute infection that brought to increased mobility of the tooth, and finally the extraction. We did not encounter any case of ankylosis. Periradicular radiolucency have been treated with the endodontic retreatment of the affected tooth, while periapical external resorption remains under strict recall regimen. Nonetheless, all patients reported a return to the normal function between the first and the second month after surgery, with the exception of the only patient that lost the autotransplanted tooth that never reported the possibility to load it. In the follow-up visit we recorded the sensation referred by the patients during the chewing at 15 days, 1 month, 3 and 6 months. All the patients referred a strange sensation at 15 days during function; the initial indication was not to load the tooth for the first month, but being in occlusion the teeth had a contact with the antagonists during chewing. This sensation was described as painless; the patients referred a sensation of force loosening as the transplanted tooth was not able to support the load. The 23.81 % of the cohort reported a normal function after 1 month; these patients referred the possibility to chewing every kind of food without limitations; the 71.43 % of the patient referred the same outcome at 2 months after surgery, even if they recognized that the loading limitation was only psychological. The 4.76 % is referred to the only lost tooth; in this case the patient was never able to load it, even if there were little improvements over time that delayed the definitive extraction.

The other investigated aspect was the satisfaction of the patient. The 100 % of the cohort referred a total satisfaction and referred that they would have repeated the experience. Surprisingly also the patient in which the transplant failed, reported the same outcome. All patients appreciated the possibility to use an autologous tooth as substitute of another compromised tooth. However it is important to consider that none of them received a previous implant or fixed partial denture rehabilitation to make a comparison.

5. Conclusions

This paper reports the longest mean follow-up of autotransplanted mature teeth with closed apex nowadays in literature. The encouraging success and survival rate suggest to take this overlooked technique in consideration in case of donor tooth availability. Moreover, the limited costs and the reported patients' satisfaction are important indicators supporting this treatment alternative. According to the study's

limitations and the general methodological criticism of the current body of evidence, researchers should focus on RCT or controlled trials to better assess the non-inferiority of this treatment, in respect to implant rehabilitation.

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CRedit authorship contribution statement

Luca Boschini: Conceptualization, Data curation, Supervision, Writing - original draft, Writing - review & editing. **Michele Melillo:** Formal analysis, Writing - review & editing. **Federico Berton:** Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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