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Factors Influencing the Long-Term Prognosis of Autotransplanted Teeth with Complete Root Formation: A Systematic Review

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Abstract

Introduction: Autotransplantation of teeth with complete root formation is indicated for replacement of teeth lost as a result of dental caries, periodontal disease, or trauma in adult patients. The present study aims at assessing the factors influencing long-term prognosis of autotransplanted teeth with complete root formation.

Methods: An electronic literature search was conducted in several databases, including PubMed, MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, and Cochrane Oral Health Group Trials, Register databases from January 1978 through July 2015. Factors potentially contributing to the tooth survival and clinical outcomes were recorded and analyzed. Weighted mean of survival rate and successful rate were also meta-analyzed among selected studies with a follow-up ≥ five years.

Results: Seven articles fulfilled the inclusion criteria. Selected studies reported a follow-up period ranging from two months to 11 years, and 5-year survival rates ranging between 76% and 85%. Weighted mean five-year survival rate was 82.1%. Overall, age of the patient, health and types of donor tooth, extraoral storage time, surgeons' experience, root anatomy, health of periodontium, and duration of tooth absence, were decisive factors for the success of the procedure. The mean NOS value was 5.86 ± 0.38, representing an acceptable level of evidence.

Conclusions: The current study systematically reviewed the potential factors influencing the long-term prognosis of autotransplanted teeth with complete root formation. The five-year survival rate and success rate of this procedure were 82.1% and 75.6% respectively. Clinicians should take all these factors into consideration when planning an autotransplant procedure.

Keywords: Tooth autotransplantation; Prognosis; Tooth loss; Autologous tooth transplantation

Introduction

Autogenous tooth transplantation can be defined as the surgical movement of a tooth from a position to another location in the mouth of the same individual for replacement of a tooth lost as a result of dental caries, periodontal disease, or trauma in adult patients [1]. Survival rates of this procedure varied from 74%-100% [2-8] as reported by several previous studies.

A large number of clinical trials on tooth autotransplantation have focused on teeth with incompletely formed roots and described factors such as the root development and eruption stage of the donor tooth, pulpal healing status, and root resorption of the transplanted tooth [6-9]. More recent studies reported the autotransplantation of teeth with complete root formation [10-15]. Different preoperative and operative conditions have been analyzed, and vary among studies [1-5,8,10-12].

Autotransplantation of teeth with complete root formation is indicated for replacement of one or more teeth lost as a result of dental caries, periodontal disease, or trauma in adult patients [11-14,16]; however, the risk of failure of this procedure is always present [1-4,9-11,17-21]. It has been proposed that the major cause for unsuccessful autotransplantation of teeth with complete root formation is the failure of initial healing and replacement root resorption with periodontal inflammation. Pocket depth and a history of root canal treatment of donor teeth appeared to statistically increase the risk of unsuccessful transplantation [10]. The maintenance of healthy periodontal ligament cells and good tissue adaptation has been considered as the most important considerations for successful tooth autotransplant [2,3-5].

To date, there is still no consensus, achievable by a well-designed systematic review, which set of factors play a role in the prognosis of autotransplanted teeth with complete root formation. The present study aims at assessing the factors influencing long-term prognosis of autotransplanted teeth with complete root formation.

Material and Methods

Information sources and development of focused question

An electronic literature search was conducted by one reviewer (MR) in several databases, including PubMed, MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, and Cochrane Oral Health Group Trials Register for articles written in English from January 1978 through July 2015. The following PICO (patient, intervention, comparison, and outcome) question was aimed to be answered: What are the factors influencing the long-term prognosis of autotransplanted teeth with complete root formation?

Screening process

Combinations of controlled terms (MeSH and EMTREE) and keywords were used whenever possible. The search terms used for the

search in PubMed were as follows: [mh] represents the MeSH terms, [tiab] represents title and/or abstract, [pt] represents publication type, and [la] represents language: ("autotransplantation"[mh] OR "tooth autotransplantation, survival rate"[tiab] OR ("autologous tooth transplantation, prognosis"[mh] OR "tooth loss"[mh]) AND ("autotransplantation"[tiab] OR "tooth autotransplantation"[mh])) AND (prognosis [tiab]) AND English [la] NOT (letter [pt] OR comment [pt] OR editorial [pt]) NOT ("animals"[mh] NOT "humans"[mh]). For the screening process in EMBASE, Cochrane Central Register of Controlled Trials, and Cochrane Oral Health Group Trials Register databases, the following terms were used: "tooth autotransplantation", "autologous tooth transplantation", "tooth autotransplantation" or "autologous tooth transplantation" in combination with "prognosis" or "autologous tooth transplantation" or "tooth loss" or "survival rate". A manual search of journals from July 1978 through July 2015, including Journal of Endodontics, Journal of Oral and Maxillofacial Surgery, Journal of Dental Research, Dental Traumatology, American Journal of Orthodontics and Dentofacial Orthopedics, Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology, Journal of Perodontology, British Journal of Maxillofacial Surgery and British Dental Journal, was performed to ensure a thorough screening process. References in the excluded articles were also checked to find studies that fulfilled the inclusion criteria.

Eligibility criteria

Articles were included in this systematic review if they met the following inclusion criteria: prospective or retrospective human clinical trials in which the preoperative and operative prognostic factors were studied. Included articles had to report the autotransplant survival for more than 12 months, have a sample size of at least 10 permanent transplanted teeth, report the teeth with complete root formation and a closed apical foramen, and publication in English. Accordingly, several factors were extracted from the selected studies and analyzed (if possible): 1) age; 2); damage to PDL; 3) apical anatomy; 4) unilateral/bilateral transplant; 5) recipient jaw; 6) complication at surgery; 7) patient's systemic conditions; 8) adjustment made on recipient site; 9) gender; 10) extraoral time; and 11) initial stability. Conversely, case reports, literature reviews, animal studies, studies in which information was not clear or was inconsistent, was excluded from this systematic review. Additionally, it is important to note that nonrandomized clinical trials might be subjected to a higher risk of bias [22]. For that reason, the Newcastle-Ottawa scale (NOS) was used to assess, by two masked examiners (MR and AP), the quality of such studies for a proper understanding of nonrandomized studies [23].

Data analyses

Due to the lack of well-conducted randomized clinical trials included in the current study, most of the clinical factors contributing to long-term prognosis of autotransplanted teeth with complete root formation in the current review presented the data extracted from the included studies in a descriptive way. Survival and success rates were meta-analyzed with a computer program (Comprehensive Meta-analysis Version 2, Biostat, Englewood, NJ, USA). Only studies reporting a follow up period of ≥ five years were pooled. Random effects meta-analyses of the selected studies were applied to avoid any bias caused by methodological differences among studies. Forest plots were produced to graphically represent weighted mean (WM) and 95% confidence interval using number of autotransplanted teeth as the analysis unit.

Results

Study selection

The PubMed database search resulted in a total of 148 articles; EMBASE database search produced 1221 articles; and the Cochrane Library provided five articles. Ninety-three articles were classified as relevant to the question of the review. After the initial screening, 22 articles were selected for additional evaluation of the full-text version. Of these, only seven articles fulfilled the inclusion criteria and were subsequently analyzed in this systematic review. The selection process is reported as figure 1.

All seven clinical autologous transplantation tooth prognosis studies selected fell into the level of evidence three for the Center for Evidence-Based Medicine at Oxford because they were case control studies. No RCTs or Cohort studies fulfilling levels of evidence one and two were found in the databases analyzed. Level of evidence 4 included 10 low-quality case-control studies, 21 case series of teeth with complete root formation, 34 case series of teeth with incomplete root development, 15 case series combining complete and incomplete root formation and, finally, six descriptive epidemiological studies. Level of evidence 5, including case reports and literature reviews were excluded as set in exclusion criteria. The demographic information of the selected articles is reported in table 1 [1,2,10,11,24-26].

Survival rate & Success rate

Five studies [10,11,24-26] reported data on five-year survival rate and one study [1] reported data on 10-year survival rate. The WM was 82.1% (95% CI: 77.1% to 86.2%, figure 2 [1,10,11,24-26] with a p value chi-square test of 0.51, representing a low heterogeneity among the selected studies. Additionally, three studies [10,24,25] reported data on five-year success rate and one study [1] reported data on 10-year success rate. The WM was 75.6% (95% CI: 60.4% to 86.3%, figure 3 [1,10,24,25] with a p value chi-square test of 0.36, representing a low heterogeneity among the selected studies.

Risk of bias assessment

Since no RCT was included in the study, the NOS [performed by two masked examiners (MR and AP)] were used to assess the quality of all the included studies for a proper understanding of nonrandomized studies [23]. The mean NOS value for the included studies in the present systematic review is 5.86 ± 0.38, displaying an acceptable level of evidence (Figure 4).

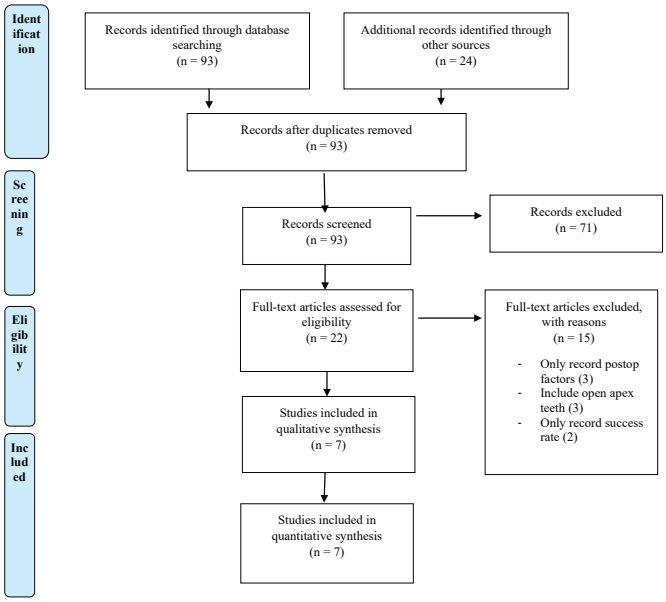

Figure 1: Flow chart illustrating the publication selection process.

Authors (year)	Design	Subjects		Study Design			Outcome	Factors					Main conclusions
		N	Age/Gender	Follow-up period	Donor tooth	Recipient site	Survival rate	Extraoral time	Endodontic treatment	Antibiotics	Fixation	Position in the occlusal plane	
Kim et al. (2005) [2]	CS	182	36years 80 m 102f	2 to 60months	1incisor 1canine 12 premolars 168 molars	NA	NA	7.58 minutes	Before extraction	Yes	NA	Proper	Most transplanted teeth showed complete healing between postoperative 2 to 8 months. The transplanted teeth with a good initial stability showed better initial healing.
Schwartz et al. (1985) [26]	Retro,CS	291	16.8 years 121m 170f	9.6 years	2 incisors45 canines121 premolars123 molars	NA	5 years (76.2%)10 years (59.6%)	NA	Perioperatively: Extraoral (13.9%) Conventional (28%)	Yes	Flexible (46.8%) Rigid (37.6%) Without fixation (15.6%)	Retained (74.5%) Subocclusion (9.3%) Occlusion (16.2%)	Developmental stage of the graft, age of the patient, donor tooth type, ectopia of the donor tooth, extraoral storage of the graft, and oral surgeon were decisive factors for the success of this procedure.
Aoyama et al. (2012) [11]	CS	259	40 years104m 155f	35.6 months	112 maxillary147 mandibular	Maxilla (22.4%) Mandible (77.6%)	1 year (96.8%) 5 years (84.4%)	NA	3 weeks after operation Conventional	Yes	Sutures, orthodontic wire and resin for 3 weeks	Infraocclusion	History of root canal treatment of donor tooth, multirooted, maxillary tooth as a donor, and duration of tooth absence at recipient site remained significantly associated with unsuccessful transplantation.
Kvint et al. (2010) [25]	CS	215	15.2 years114m 101f	2.4-4.8 years	31 maxillary canines7 mandibular canines 55 maxillary premolars 21 mandibular premolars71 maxillary molars 30 mandibular molars	Maxilla (79 cases) Mandible (136 cases)	5 years (88.3%) Successful (81%)	NA	One month postoperatively	Yes	NA	NA	The success rate was 81%. The highest success rate was for transplantation of premolars to the maxillary incisor region (100%).
Sugai et al. (2010) [10]	CS	117	39 years41m 68f	40.9 months	1 maxillary canine11 maxillary premolars15 mandibular premolars 40 maxillary molars 50 mandibular molars	Incisor position (7 cases) Premolar position(21 cases) Molar position (89 cases)	1 year (96%) 5 years (84%) Successful (88%)	NA	3 weeks postoperatively Conventional ($CaOH_2$)	Yes	Orthodontic wire and resin with 4 -0 silk sutures for 3 weeks	NA	Factors associated with unsuccessful transplantation were age ≥ 40, molar tooth as donor, probing pocket depth to 4 mm or more, history of root canal treatment, multirooted teeth and fixation with sutures.
Gonnissen et al. (2010) [1]	CS	73	20.7 years34m 25f	11 years	67 maxillary canines 3 mandibular canines2 mandibular molars	Canine position in the maxilla (100%)	10 years (75.3%) Successful (57.5%)	NA	Patient>20 years Closed apex	Yes	Suture, orthodontic wire and resin	Infraocclusion	Autotransplantation of impacted canines might have a successful outcome 11 years after surgery. The success rate increased when performing in younger patients.
Mejàre et al. (2004) [24]	CS	50	36.7 years	10 years	20 maxillary third molars29 mandibular third molars	First or second molar position	1 year (97.9%) 5 years (81.4%) Successful (68%)	NA	3 or 4 weeks postoperatively Conventional (CaOH2)	Yes	Interdental sutures (39 cases) Luxatemp(10 cases)	NA	Autotransplantation of mature third molar teeth is a reasonable treatment alternative to conventional prosthetic rehabilitation or implant treatment in cases of partial edentulism.

Table 1: Features of the included articles | NA: Data not available; CS: case series; Retro: retrospective; N: number; avg.: average; f: females; m: males; T: test group; C: control group

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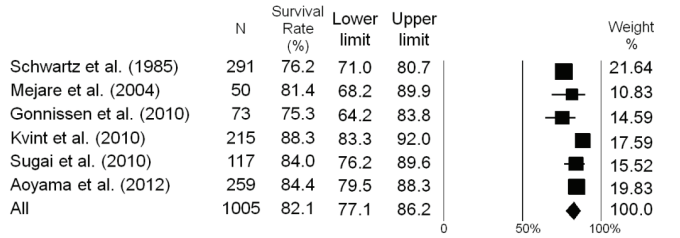

Figure 2: Weighted mean of the survival rate with a follow-up ≥ five years among the selected studies

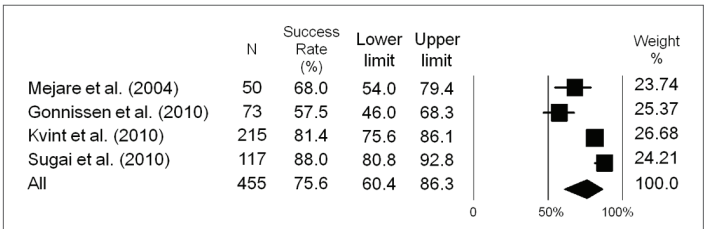

Figure 3: Weighted mean of the success rate with a follow-up ≥ five years among the selected studies

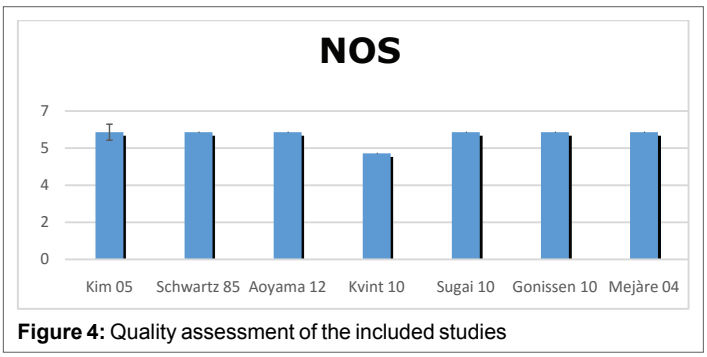

Figure 4: Quality assessment of the included studies

Discussion

The objective of our review was to evaluate the preoperative and operative factors that may play a role in the long-term success of the autotransplanted teeth with closed apices. The factors that lead to success have been extensively investigated, and it is well documented how extracted teeth gain complete function and good esthetics when replantation happens in ideal conditions [27].

Patient selection

Patient selection is very important for auto-transplantation success. Candidates must be in a good health, demonstrate an excellent level of oral hygiene, and be amenable to regular dental care; otherwise a successful outcome of auto-transplantation could be jeopardized. Patients must be able to follow post-operative instructions and be available for follow-up visits. Above all, the patients must have a suitable recipient site and donor tooth [27].

Schwartz et al. [26] do not recommend the procedure for patients with a multiedentulous area, those who are prone to dental caries, those with poor oral hygiene, and those with systemic diseases contraindicative to surgery. Tanaka et al. [28] contraindicated surgery in presence of systemic diseases such as histiocytosis and osteomyelitis.

The patient's oral hygiene is an important factor to consider**.** Berglund et al. [29] reported that inadequate oral hygiene of the patient may result in a poor healing and gingival pocket formation. In conclusion medically compromised patients and those with poor oral health are not candidates for tooth autotransplantation.

Age of patient

According to Aoyama et al. [11], aging has two problems related to the prognosis of tooth autotransplantation. Firstly, there is a decreased regeneration ability of transplanted tissue after surgery and, secondly, there is a bacterial infection of the donor tooth owing to the increasing rate of dental caries and periodontal inflammation of the donor tooth. Conversely, Yoshino et al. [30] found that age was not a significant factor in the survival of transplanted teeth, which is contradictory to previous reports by Gonnissen et al. [1] who found that autologous transplantation performed better in younger patients as well as Kvint et al. [25] who considered patients under 20 years of age as the best candidates for autologous tooth transplantation. On the other hand, Sugai et al. [10] found a significant association between patients of 40 years of age or older and the poorest prognosis. Schwartz et al. [26] concluded that the age group ≥ 25 years showed a poorer prognosis compared with those <25 years of age. Yoshino's report, however, focused on third molars as donor teeth. In a previous study, Yoshino's group had found a significant difference between younger patients (under 40) and older patients (40 and over) with a log-rank test [31]. In a recent study by Mendoza-Mendoza et al. [32], where autotransplantation was performed from premolars to maxillary central incisor region in patients aged 9-13, it was concluded that autotransplantation of donor teeth, at the stage of one half to three quarter of their expected root length, can provide a successful treatment solution for patients older than 14 years. Similarly, Altonen et al. [33] found better outcomes when patients were in the group of 13-20 years of age versus 21-30 and 31-47 years of age, and it was concluded that the prognosis for transplantation was found to be fairly good for patients under 20 years of age but poorer for older age groups. Nimcenko et al. [27] stated that the age of the patient must be considered when planning this type of procedure, however, Bae et al. [17] concluded that even if the donor tooth has complete root formation a high success rate can be achieved if the cases are selected and treated properly. It can be concluded that patients younger than 20 years of age will have a greater chance of a successful outcome.

Recipient site

Aoyama et al. [11] found no statistically significant differences between the maxilla and mandible. The multivariate Cox proportional hazards regression analysis, however, showed that duration of tooth absence of 2.5 months or more at the recipient site emerges as a significant factor in prognosis. This period of time is thought to represent a narrow alveolar ridge in the site because of atrophy of the alveolar ridge after a long absence of teeth. Preparation of narrow recipient sites frequently results in loss of buccal bone coverage of the transplanted tooth.

According to Fong [34], maxillary transplants should not be done because of the extreme variation in the size and shape of the maxillary third molars and because of the proximity of the maxillary antrum to the sockets. In a study by Bae et al. [17] for sites adjacent to the maxillary sinus, the septal bone was elevated from the maxillary sinus floor and then the tooth was transplanted.

Kvint [25] followed up 215 cases of autologous transplantation; 64 teeth were transplanted within the maxilla, 93 from maxilla to mandible, 43 within the mandible, and 15 from mandible to maxilla. The highest success rate was for transplantation of premolars to the maxillary incisor region (100%). In the same study, the authors found that adequate mesiodistal and vertical space is required at the recipient site, and the teeth were most frequently transplanted to recipient sites that lacked buccal and lingual alveolar bone. The major priority is to avoid damage to the periodontal

ligament of the donor tooth. Normal mobility was achieved within three months and corresponded with radiographic evidence of bone formation. It can be concluded that the posterior maxilla is the worst recipient site, whereas the anterior maxillary region appears to be the area of higher success.

Donor tooth

The prognosis for transplantation to the premolar area is considered to be significantly better than transplantation to the molar area. To some extent this might be explained by variations in bone morphology, the vascularity of the recipient bed, and surgical access. Transplants to the premolar region are often indicated as a result of oligodontia and so are done at a relatively young age [18].

Sugai et al. [10] found an association between the depth of the pocket of the donor tooth and the outcome of the transplantation. The author believes that a pocket depth of 4 mm or more was associated with a poor prognosis due to the lack of a healthy periodontal ligament (PDL), which causes periodontal inflammation and replacement root resorption [10]. Progressive root resorption and ankylosis are strongly correlated with damage to the root surface during the surgery. A difference in success rate between premolars and molars might be expected because anatomical variations and the difficulty of surgical and endodontic access [35]. Akiyama et al. [36] conducted a clinical and radiographic study of the relationship between the macroscopic condition of the root surface of donor teeth and the clinical prognosis after transplantation and found no noteworthy difference between areas with exposed cementum and those with an intact PDL. Replacement root resorption was observed in teeth with cemental injury.

A more favorable prognosis was reported for donor teeth with incomplete root development. The position of the tooth and the extent and type of trauma during surgery are also important factors, along with extraoral exposure of the extracted tooth and endodontic treatment [37]. The donor tooth position in the arch has been analyzed by Schwartz et al. [26], and found that ectopia of the donor teeth, present in ninety transplantations, compared to grafts with a normal position of the donor tooth considering the developmental stage, did not show a significant influence on the prognosis. Transplantations where endodontic treatment preoperatively was carried out, however, showed a significantly worse prognosis than transplantations where this was not done. It can be concluded that premolars have a significantly better prognosis than molars. Tooth anatomy, access to the surgical area and periodontal health, are determining factors to predict success [6].

Clinical factors

There is a relationship between complicating factors at the time of surgery and prolonged extraoral exposure of the donor tooth after extraction [2]. Complications encountered during surgery often lead to a prolonged extraoral interval and increases the risk of damage to the PDL. This means that technical problems during surgery are associated with a lower success rate.

Kim et al. [2] prepared the recipient site using a CARP (Computer-Aided Rapid Prototyping) tooth model prior to extraction in an attempt to reduce the extraoral time. Although they found no relationship between extraoral time and root resorption or ankylosis, it is evident that a shorter extraoral time is favorable for the survival of the PDL cells. Surgical difficulties may be another problem because every tooth has a different size and shape. Therefore, techniques to facilitate the recipient bone contouring or to provide a standardized donor tooth by such as tissue and genetic engineering would be useful.

Kvint et al. [25] concluded that prolonged extraoral exposure of the transplant tooth after extraction was associated with complications at surgery and, in turn, that complications at surgery, such as a difficult extraction, deviant root anatomy, or damaged periodontium, were predictors of lower success. Altonen et al. [33] found the causes of the failure of transplantation were considered to include damage of the transplant during removal from a deep palatal malposition, poor regeneration of the bone around the transplant, and chronic periodontal infection. Kristerson [38] reported that damage to the PDL and the combination of damage to the PDL and pulp tissue are important in progressive root resorption. In 14 unsuccessful cases, the major causes were failure of the initial healing and replacement root resorption.

Watanabe et al. [12] found a strong relationship between inadequate root canal obturation and transplantation loss. They noted that in cases where there was a low quality root canal filling, transplanted tooth loss by replacement resorption, inflammatory resorption, furcation involvement, or periapical lesion development occurred. It has been proposed that early endodontic treatment would prevent passage of degradation products and toxins from non-vital pulp tissue into the surrounding tissues through the apical foramen, accessory canals, or dentinal tubules, thus reducing the risks of resorption [25,27]. Andreasen et al. [6] reported 98% of five-year survival rate when root canals were done four weeks after transplantation of premolars with complete root formation. Conversely, when the root canal therapy of the donor tooth was done prior the surgery, unsuccessful outcomes of transplantation were reported [11].

Schwartz et al. [26] compared transplants performed by experienced surgeons with those carried out by less-experienced clinicians and increased survival was observed in transplants performed by the most experienced oral surgeons. This paper also demonstrated better results in modern treatment over older techniques. One of the factors contributing to successful autotransplantation is vital intact PDL fibers which play an important role in healing. Usually, the PDL fibers on the walls of the surrounding prepared sockets are absent. It is desirable, therefore, to extract a tooth with as much PDL attached to it as possible as it seems to be effective in preventing root resorption [39-42].

Taking all together, decreased extraoral time of donor tooth, adequate endodontic obturation, and operator experience are critical for success.

Most clinicians value the importance of antibiotics in the success of autotransplanted teeth. Schwartz et al. [26] used the penicillin family during the first operative week and found no significant influence on the survival of the transplant. Sugai et al. [10] and Aoyama et al. [11] prescribed cefditoren pivoxil and benzethonium chloride mouthwash to all patients. Similarly, Kvint et al. [25] prescribed Penicillin VK for seven days and mouth rinses with chlorhexidine twice a day. Mejàre et al. [24] administered 2g Phenoxymethylpenicillin one hour prior to surgery and 1g three times a day for 10 days postoperatively, however, no significant results were described.

Use of antibiotic does not improve success, however good oral hygiene and mouthwashes are recommended.

Schwartz et al. [26] found no statistically significant difference between rigid fixations for more than one week compared with a fixation period of up to one week. Studies of Aoyama et al. [11] also concluded that method of fixation did not influence the successful transplantation of teeth. Sugai et al. [10], however, stated that transplants fixed with sutures had a significantly lower survival rate than transplants fixed with wire and resin. These authors recommended fixation when the initial stability is poor; it is also considered that extensive fixation periods could lead to the development of gingivitis due to the difficulties in achieving good oral hygiene in the surgical area.

The position of the transplanted tooth in the occlusal plane was described by Lundberg and Isaksson [18] who recommended that immature donor teeth should be placed in infraocclusion and mature

donor teeth in occlusion or slight infraocclusion. The work of Kvint et al. [25] on 215 patients followed the recommendations of this study. Aoyama et al. [11] placed the transplanted tooth in the infraocclusion position. Overall, position of the transplant below the plane of occlusion is the recommendation for this surgical procedure.

None of the studies showed a definitive relationship between time of suture removal and success. Sutures were removed seven days after surgery [2,10,25] in most studies. It is a parameter that should be taken into account because of the possibility of plaque accumulation that could cause localized gingivitis and interfere in the healing process.

The success [1,4,9,10,12,18,24,25] and survival [1,4,9-12,24-26] rates for autotransplantation differ widely with reported results ranging from 50% to nearly 100% in five-year and longer follow up periods. This review is consistent with the literature and the studies included for meta-analysis showed 82.1% and 75.6% of survival and success rates respectively. These results show that with proper case selection and technique, tooth autotransplantation can be a viable treatment modality with a long-term predictability.

Conclusion

The current study systematically reviewed the potential factors influencing the long-term prognosis of autotransplanted teeth with complete root formation. A five-year survival rate and success rate of this procedure was 82.1% and 75.6%, respectively. Clinicians should take all these factors into consideration when planning an autotransplant procedure.

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