

Tooth transplantation and orthodontic movements

ABSTRACT

Dental autotransplants have been performed successfully for many years, but little has been written about its relationship with orthodontics. This article is a review which analyses and highlights all the details about the orthodontic movement in autotransplanted teeth according to their root development. The inclusion criteria for the analysis were the following: human and animal model studies, retrospective and prospective clinical studies, case series, systematic reviews, any tooth type, minimum 20 transplants, languages of publication in Spanish and English, follow-up of at least 1 year, and publications between 1985 and 2017. After examining the titles and abstracts, 168 articles were evaluated, discarding those that were not within the inclusion criteria for agreement and relationship to the research topic.

Keywords: Autotransplantation, orthodontics autotransplantation and dental autotransplant, tooth autotransplantation

INTRODUCTION

The tooth autotransplantation is a treatment that consists of the placement of a tooth in an alveolus or edentulous receptor zone that has been previously surgically prepared. This involves transplanting an impacted or erupting tooth from one site to another in the same individual.^[1] It is a treatment that has been shown to be effective in replacing missing teeth and success rates reported in the literature vary from 74% to 100%.^[2-4]

It is a beneficial treatment for patients who are growing.^[2] On the other hand, in adult patients, since there is no bone growth, it is more frequent for them to be treated with fixed tooth-supported prostheses and/or implants.^[2,5] Autotransplantation is a treatment option that provides clear advantages in terms of function, esthetics and cost of treatment, as well as good long-term prognosis.^[1] It is indicated to do an autotransplantation in impacted teeth, in agenesis, in dental losses as a consequence of caries or periodontal and periodontal lesions, and in traumas.^[2,6] In general, a transplant is appropriate when a tooth cannot be restored, and when a third molar or a badly positioned

tooth is not functioning.^[1,7] According to Tsukiboshi,^[8] an autotransplant is chosen before placing an implant in the following cases: patients who are treated before pubertal growth and/or patients with nonrestorative tooth that require extraction and for which there are no ideal tooth donors.

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Table 1: Authors and their studies

Author	Year	Type of study	Number of patients	Number of transplants	Root formation	Orthodontics	Follow-up
Lagerström <i>et al.</i>	1986	Longitudinal	Do not mention	59	Open apex	12 months minimum and begins 6 months after autotransplant	Do not mention
Andreasen <i>et al.</i>	1990	Longitudinal	195	370	Open and closed apex	Do not mention	1-13 years
Paulsen <i>et al.</i>	1995	Longitudinal	Do not mention	118	Open apex (3/4 and 4/4 of the length of the formed root)	3-9 months after autotransplant	Do not mention
Lundberg <i>et al.</i>	1996	Prospective	296	278 (204 open apex and 74 closed apex)	Open and closed apex	Do not mention	Do not mention
Czochrowska <i>et al.</i>	2000	Longitudinal	40	45	Open apex	Approximately 6 months after transplant	4 years
Czochrowska <i>et al.</i>	2002	Longitudinal	25	33	Open apex	Do not mention	17-41 years (26.4 years)
Jonsson <i>et al.</i>	2004	Longitudinal	32	40	Open and closed apex	4 months after transplant	10 years and 4 months
Tanaka <i>et al.</i>	2008	Longitudinal	24	28	1/2 formed root, 3/4 formed root, and fully formed root	Do not mention	4 years
Mensink <i>et al.</i>	2010	Longitudinal	44	63	Open and closed apex	3 months after transplant	From 1-5 years (average of 1.74 years)
Kvint <i>et al.</i>	2010	Longitudinal	215	215	Open and closed apex	Do not mention	Average of 4.8 years
Watanabe <i>et al.</i>	2010	Longitudinal	32	38	Closed apex	2 months after transplant	> 6 years
Denys <i>et al.</i>	2013	Retrospective	109	137	< From 1/2 of the formed root (12), from 1/2 to 3/4 parts of the formed root (84), > from 3/4 parts of the formed root (20) and closed apex (21)	3 to 9 months after transplant	1 week to 14.8 years (average 4.9 years)
Plakwicz <i>et al.</i>	2013	Prospective	19	23	Open apex	Do not mention	6-78 months (average 35 months)
Kokai <i>et al.</i>	2015	Retrospective	89	100	Closed apex	1-2 months after transplant	1.9-14.7 years (average 5.8 years)
Author	Year	Number of teeth	Number of successful teeth	Root formation	Success rate (%)	Survival rate (%)	
Andreasen <i>et al.</i>	1990	370	Do not mention	Open and closed apex	Do not mention	Open apex (95) and closed apex (98)	
Kristerson and Lagerström <i>et al.</i>	1991	50	Do not mention	Open and closed apex	82	Do not mention	
Lundberg <i>et al.</i>	1996	278	192 open apex and 62 closed apex	Open and closed apex	94 open apex and 84 closed apex	Do not mention	
Czochrowska <i>et al.</i>	2000	45	Do not mention	Open apex	93	93	
Czochrowska <i>et al.</i>	2002	33	Do not mention	Open apex	79	90	
Jonsson <i>et al.</i>	2004	40	Do not mention	Open and closed apex	92.5	97.5	
Tanaka <i>et al.</i>	2008	28	Do not mention	Open and closed apex	100	Do not mention	
Arikan <i>et al.</i>	2008	32	Do not mention	Closed apex	Do not mention	93.5	
Mensink <i>et al.</i>	2010	63	Do not mention	Open and closed apex	Do not mention	100	
Kvint <i>et al.</i>	2010	215	175	Open and closed apex	81.4	Do not mention	
Watanabe <i>et al.</i>	2010	38	Do not mention	Closed apex	63.1	86.8	
Denys <i>et al.</i>	2013	137	Do not mention	Open and closed apex	65.4	86.8	
Plakwicz <i>et al.</i>	2013	23	21	Open apex	91.3	100	
Kokai <i>et al.</i>	2015	100	Do not mention	Closed apex	71	93	

To perform an autotransplant, a treatment sequence must be performed, requiring clinical and radiographic examination, precise diagnosis, treatment plan, surgical procedure, endodontic treatment, orthodontic treatment if necessary, restoration treatment, and follow-up.^[1,8]

During the surgical protocol of dental autotransplantation, one of the key factors for the success of the short- and long-term treatment will be the correct planning of the case.^[1,8] It will be crucial to take into account the dimensions of the donor tooth and the recipient site. Before starting the surgical procedure, measurements should be taken in the three axes of space in both the donor and recipient areas. If the donor tooth is too wide, space should ideally be opened by orthodontic treatment. If orthodontic treatment cannot be performed, the dimensions of the donor tooth can be reduced by ameloplasty without exceeding 2 mm of enamel. Orthodontic planning of autotransplant cases will be one of the keys to successful treatment.^[9]

According to several authors such as Kim *et al.*,^[10] in order to reduce the extraoral time of the donor tooth and prevent injuries to the periodontal ligament, a replica of the donor tooth is made in an acrylic model. Before placing the donor tooth in the new alveolus, the replica is tested to form the recipient alveolus and see the final position of the autotransplant.

The general indication in orthodontics to perform an autotransplant is to replace the loss or agenesis of a tooth with a tooth from another region. The ideal situation occurs when the donor tooth does not have complete root development and is a premolar or a third molar.^[7,11] Almost all patients with autotransplanted teeth require orthodontic treatment to correct the malocclusion, as the transplanted tooth is often not in the ideal position. This movement must be carried out with care, as the orthodontic movement of a transplanted tooth results in some root shortening.^[7,12] The orthodontist is the most competent professional to identify available donor teeth since he or she previously evaluates the patient's general occlusal condition.^[11]

The aim of this review will be to assess the success and survival of autotransplants and to analyze all the details about the orthodontic movement in autotransplanted teeth according to their root development.

MATERIALS AND METHODS

Sources of information and bibliographic search

In order to carry out this bibliographic review, a systematic

review of studies related to dentistry, specifically orthodontics and autotransplantation was carried out. The literature was reviewed from articles found in Medline's PubMed electronic database, on the website of the journal "The Angle Orthodontist" and in the library of the International University of Catalonia. Some articles were published in journals such as *Dental Traumatology*, *American Journal of Orthodontics and Dentofacial Orthopedics*, *Journal of Clinical Periodontology*, and *Dental Press Journal of Orthodontics*. This literature search was conducted using a series of keywords such as: "tooth autotransplantation," "autotransplantation," "orthodontics autotransplantation," and "dental autotransplant."

Inclusion and exclusion criteria

The inclusion criteria for the analysis were the following: human and animal model studies, retrospective and prospective clinical studies, case series, systematic reviews, any tooth type, minimum 20 transplants, languages of publication in Spanish and English, follow-up of at least 1 year, and publications between 1985 and 2017.

The exclusion criteria were the following: *in vitro* studies, case reports, and publications before 1985.

RESULTS

Selection of studies

The initial search using the keyword "Tooth Autotransplantation" in the previously mentioned available electronic databases resulted in a total of 1067 articles available, but only 649 articles published since 1985. After examining the titles and abstracts, 168 articles were evaluated, discarding those that were not within the inclusion criteria for agreement and relationship to the research topic. The first evaluation of these articles was carried out to determine their content. After this approach, 49 articles were discarded because they were clinical case reports and were not useful for the study, another 36 articles were discarded because they did not have a minimum sample of twenty transplants, 13 were discarded because they had another research objective and did not meet the inclusion criteria, another 15 articles were discarded because they had a follow-up of < 1 year, and lastly, another 21 were discarded because they were *in vitro* studies. Finally, the remaining 34 articles that met the inclusion criteria were selected.

Survival rate

In the study by Andreasen *et al.*,^[13] they conducted a study with 370 autotransplanted teeth, with a follow-up period of 1–13 years. They achieved a survival rate of 95% in open apex and 98% in closed apex. Denys *et al.*,^[14] conducted a study of 137 autotransplanted teeth with a follow-up period of 4.9%

years. The survival rate was 86.8%. Czochrowska *et al.*^[15] conducted a study of 45 transplanted open apex premolars with a follow-up of 4 years. Achieving a 93% survival rate. In the 2002 study, a 90% survival rate was observed with a sample of 33 teeth with open apex transplanted with an average follow-up period of 26.4 years.^[16] In the study by Plakwicz *et al.*,^[9] a 100% survival rate is described in a sample of 23 transplanted premolars with open apex. Watanabe *et al.*^[17] published a study of 38 teeth with closed apex transplanted with a survival rate of 86.8%, over a follow-up period of more than 6 years. In the Kokai *et al.*^[18] study of 100 self-transplanted closed apex teeth, a survival rate of 93% was achieved [Table 1].

Success rate

In the study by Lundberg and Isaksson^[19] a success rate of 94% at the open apex and 84% at the closed apex is described. Denys *et al.*^[14] conducted a study of 137 autotransplanted teeth with a follow-up period of 4.9 years. The success rate was 65.4%.^[14] Czochrowska *et al.*^[15] conducted a study of 45 transplanted open apex premolars with a follow-up of 4 years. Achieving a 93% success rate.^[15] In the study carried out in 2002, a success rate of 79% was observed for 33 teeth with open apex transplanted with an average follow-up period of 26.4 years.^[16] In the study by Plakwicz *et al.*,^[9] a success rate of 91.3% is described in a simple of 23 transplanted premolars with open apex. Watanabe *et al.*^[17] published a study of 38 teeth with closed apex transplanted with a success rate of 63.1%, over a follow-up period of more than 6 years. In the Kokai *et al.*^[18] study of 100 self-transplanted closed apex teeth, a success rate of 71% was achieved [Table 1].

Orthodontic movement

Lennart Lagerström *et al.*^[12] apply an orthodontic 6 months movement after transplantation of teeth with open apex. Czochrowska *et al.*^[15] also describe that the ideal time to initiate orthodontic movement in teeth with an open apex is approximately 6 months after surgery. However, authors such as Paulsen^[20] initiate orthodontic movement 3-0 months after autotransplantation of teeth with open apex.

On the other hand, in autotransplants with closed apex, Watanabe *et al.*^[17] apply orthodontic movement 2 months after the tooth transplant. Moreover, in the study by Kokai *et al.*,^[18] orthodontic strength begins 1–2 months after transplantation of fully developed teeth. On the other hand, there are studies such as Jonsson and Sigurdsson^[21] that do not differentiate between the open and closed apex and initiate orthodontic movement 4 months after transplantation. Neither in the article by Mensink *et al.*^[2] differentiate between the open and closed apex and orthodontic movement begins 3 months after surgery. Finally, Denys *et al.*^[14] believe that orthodontic

movement in both open and closed apex transplantation should begin 3–9 months after autotransplantation [Table 1].

DISCUSSION

In order to understand and classify an autotransplant as successful, authors Schwartz *et al.*,^[22] Kristerson and Lagerström *et al.*,^[23] and Kugelberg *et al.*^[24] described and referred to the following three criteria described by Czochrowska *et al.*^[16] in their articles:

- The hard and soft periodontal tissues adjacent to the transplanted tooth should remain normal and unchanged
- Absence of progressive root resorption
- Coronaradicular ratio < 1, therefore, the supraosseous part shorter than the infraosseous part.

In our opinion, we agree with several other authors such as Schawartz *et al.*,^[22] Kristerson y Lagerström *et al.*,^[23] Kugelberg *et al.*,^[24] Czochrowska *et al.*,^[15,16] Kokai *et al.*,^[14,18,25] and Denys *et al.*,^[14] since they take into account the soft tissues, the development of the root of the transplanted tooth, and mobility, that there is no ankylosis or apical infection, and above all emphasize the fact of a coronaradicular relationship < 1. This last criterion is necessary to keep the tooth in the mouth.^[18]

Andreasen *et al.*^[4,13,26] state that donor teeth in the early stages of root development are more likely to stop root growth than those with more mature roots but open root apex.^[27,28] As Czochrowska *et al.*^[15,16] comment in their article, autotransplantation of teeth with fully formed roots reduces success rates. Articles corroborate that the success of autotransplantation decreases when the donor teeth have fully formed roots and also indicates that the ideal time for transplantation is when the donor tooth has half or three-quarters of the root formed. We especially like classifications that regardless of the radiographic success criteria, the teeth are in the mouth without any apparent problem. We have to base ourselves on the fact that there are no signs or symptoms, and that the tooth is in the mouth and does not show any type of symptomatology.^[14,18,22,23,25,29]

According to most articles on autotransplantation of teeth with open apex, we should wait for the pulp to regenerate, as it has been observed that the apical foramen influences the revascularization of the pulp. As Andreasen *et al.*,^[13] Tsukiboshi,^[1,8] and Rocha *et al.*^[14] state that a pulp cure will be achieved when the diameter of the apical foramen is at least 1 mm. Root canal treatment should be performed promptly when inflammatory resorption of the root is suspected or if irreversible pulpitis is diagnosed.^[30] On the other hand, all

the authors of this review state that in the case of teeth with a closed apex, root canal treatment should always be carried out after transplantation, as there will be no regeneration of the pulp.^[1,8,14] We have observed that a higher success rate is obtained if endodontics is performed at 2 weeks postoperatively than not at 4 weeks.^[8,10,14,31,32]

The Moorrees *et al.* classification^[12,18,21,33] is based on the evaluation of the stages of root development and is divided into seven groups. The stages that are most suitable for the success of a dental autotransplant are between stages 3 and 6 of Moorrees. A grade higher than 4, at least three quarters of the length of the root formed, will ensure a sufficiently long root that can be preserved if no root development occurs after transplantation.^[26,28] Ideally, the aim is to transplant a tooth that is at its maximum degree of root development and that has revascularization potential (apex opening >1 mm radiographically).^[28] For an autotransplant to be successful, the following must be taken into account: the healing of the pulp, the healing of the periodontal ligament, and the optimum root length. It has been seen that there is better pulp healing in initial stages, since the apex is open and is going to revascularize, that not in stages such as 7 that the apex is already closed and the pulp is not going to revascularize, but we will have to perform endodontics. We observed that the exact opposite happens with the optimum root length, which causes that we are going to have more success in the last stages and less success in the first stages, as there will be less root development. Finally, we observed that the healing of the periodontal ligament remains quite stable. Therefore, we observed that the ideal time for autotransplantation is when these three variables are at their best, specifically between stages 3 and 5.^[12,18,34]

We have noticed that there is a relationship between the orthodontic movement of a transplanted tooth and the reabsorption of the root, but that has little clinical relevance.^[12] Lagerström and Kristerson *et al.*^[12] and Paulsen^[20] state that there is a minimal difference between the length of the final root of treated and nonorthodontically treated autotransplanted teeth. In the study by Lagerström and Kristerson *et al.*,^[12] it is observed that the final root length of transplanted teeth without application of an orthodontic movement is 13.24 ± 2.75 , whereas the final root length of transplanted teeth with the orthodontic application is 13.08 ± 2.10 . The authors have found no differences, and therefore, these forces can be used in transplants.^[12] We can conclude that combined surgical and orthodontic treatment is a viable alternative in cases of agenesis, as there will be no clinical difference between whether they are treated with orthodontics or not. The main factor causing root

resorption is periodontal ligament trauma during donor tooth transplantation.^[10,14,20]

Some clinical or experimental studies have suggested that prior application of mechanical stimuli to donor teeth may widen the periodontal ligament and facilitate extraction, which may reduce damage to the periodontal ligament that occurs during extraction of the donor tooth while decreasing the risk of root resorption after transplantation. Suzaki *et al.* conducted a study with rats to investigate the effect of a previous application of orthodontic forces to donor teeth and to evaluate the results before and after replanting. After 7 days of applying an orthodontic force, it was observed that the area of the periodontal ligament in the buccal and palatal was wider in the experimental group than in the control group. It was also observed that the apical zone of the alveolus was wider in the experimental group. This procedure increases the width of the periodontal ligament around the root of the tooth to be transplanted; therefore, preapplication of an orthodontic force to the donor tooth may be advantageous for autotransplantation.^[11,25]

According to the bibliographic review, we have carried out we see that there are many articles that do not differentiate the moment of initiating orthodontic movement between a transplanted tooth with an open or closed apex. Some of the authors who do not differentiate between open and closed apex are Denys *et al.*,^[14] Jonsson and Sigurdsson,^[21] and Mensink *et al.*^[2] Others, such as Mensink *et al.*^[2] initiate orthodontic movement 3 months after transplantation and achieve a success rate of 98%.

We can conclude that the ideal moment to start the orthodontic movement before a tooth with an open apex varies depending on the author. According to Lagerström *et al.*,^[12] we should start the orthodontic movement 6 months after the autotransplant. Paulsen^[20] also recommends starting orthodontic movement 3–9 months after transplantation. And finally, Czochrowska *et al.*^[15] recommend starting orthodontic movement 6 months after the surgical procedure. In our opinion, when we transplant a tooth with an open apex, we will start the orthodontic movement around 6 months after the autotransplant. We must wait a while to avoid interfering with the root development of the donor tooth. It is best to perform the movement after periodontal healing and before complete obliteration of the pulp duct. Periodontal healing occurs about 8 weeks after transplantation, so we should wait at least 2 months before starting the orthodontic movement. We assume that in a tooth with an open apex, we should wait longer for greater root development and pulp healing. The longer we wait to apply the force, the more the root will form

and the more good results we will have.^[12,15,17,20] We can see that the success rate of the study by Czochrowska *et al.*^[15] applying an orthodontic movement 6 months after the transplant of a tooth with an open apex is 93%.

On the other hand, we have observed that the ideal moment to perform an orthodontic movement of a transplanted tooth with a closed apex will be 2 months after having performed the surgery. According to Kokai *et al.*,^[18] the orthodontic movement should be started from 4 to 8 weeks after the transplant. On the other hand, according to Watanabe *et al.*,^[17] it should be started 2 months after the transplant when it has healed periodontally. In our opinion, we see that the two authors agree quite a lot, and we come to the conclusion that the ideal time would be 2 months after transplantation once periodontal healing has taken place. In the study by Kokai *et al.*,^[18] a success of 71% is achieved by applying an orthodontic movement from 1 to 2 months after the tooth transplant with a closed apex. Moreover, in the study of Watanabe *et al.*,^[17] a success of 65.4% is obtained by applying an orthodontic force 2 months after the transplant. This percentage difference may be due to the different sample, follow-up time, or the success criteria required. There is a lot of variability in the results due to the different samples that are published. This difference in results could be due to the size of the sample or the type of tooth transplanted, the variations in the follow-up periods, the different success criteria demanded by each author, etc. In addition, there are few articles that mention the ideal moment to start an orthodontic movement in a transplanted tooth.

When a transplant is performed, the new alveolus receptor is placed in infraocclusion in relation to the rest of the adjacent teeth. According to Lundberg and Isaksson^[19] teeth with closed apices are placed slightly below the occlusal plane, and teeth with open apices are placed a little more in infraocclusion. We believe that the ideal would be, since it no longer has eruptive power, to place it just in infraocclusion so that it does not disturb and that it allows a certain degree of the eruption. In addition, it would be prudent to let the tooth erupt on its own, without forcing it by applying an orthodontic extrusion movement. In this way, a more natural eruption of the tooth is obtained and time is given for the periodontal ligament to be consolidated. Ideally, wait until the transplanted tooth erupts to the occlusal level of the remaining teeth before starting an orthodontic movement. For this reason, we cannot determine exactly when to start the orthodontic movement, as this process of extrusion of the tooth itself will depend on each case. Although according to the articles studied, we can say that we will apply an orthodontic movement 2 months after the transplant in a closed apex, and 6 months after the

transplant in an open apex, the eruption of the transplanted tooth must be taken into account in order to determine at what moment the force of the application should start.

Finally, it should be borne in mind that when performing an autotransplant at the time of extraction, the periodontal ligament may be damaged. If this happens to us, there is a better chance that the transplant will end up ankylosing. If ankylosis of the tooth is expected due to damage to the periodontal ligament during the surgical procedure, we should consider initiating orthodontic movement earlier than mentioned above. Ankylosis can be improved by the patients' chewing during periodontal healing or by extruding previously dislocated teeth orthodontically. A tooth that is ankylosed should not be applied an orthodontic movement without having been previously dislocated.

CONCLUSION

Autotransplantation is a good treatment option, as it has multiple advantages over other alternatives such as implants or other types of prosthetic restorations. The advantages are biocompatibility, high long-term success rate, low economic cost, as well as good dental and gingival esthetics.

In order to be successful with autologous transplants, it is necessary to follow an action protocol:

- Three-dimensional planning and orthodontics before the case
- Atraumatic surgical procedure
- Pulp vitality of the donor tooth and root length consideration in order to be successful. Tooth with open apex wait for it to revascularize. Instead, tooth with closed apex perform root canal 2 weeks after transplant
- Monitoring the case
- Application of orthodontic force in an open apex around 6 months after the autotransplant. On the other hand, the ideal moment to perform an orthodontic movement in a closed apex will be 2 months after having performed the surgery. In addition, we have to take into account the eruption of the transplanted tooth to finish determining when we begin to apply the force.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Mitsuhiro Tsukiboshi D. Autotransplantation of Teeth: Requirements

- for success. *Dent Traumatol* 2002;18:157-80.
2. Mensink G, Van Merkesteyn R. Autotransplantation of premolars. *Br Dent J* 2010;208:109-11.
 3. Marques-Ferreira M, Rabaça-Botelho MF, Carvalho L, Oliveiros B, Palmeirão-Carrilho EV. Autogenous tooth transplantation: Evaluation of pulp tissue regeneration. *Med Oral Patol Oral Cir Bucal* 2011;16.
 4. Andreasen JO, Paulsen HU, Zhijie Y, Ahlquist R, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part III. Periodontal healing subsequent to transplantation. *Eur J Orthod*. 1990;12:14-24.
 5. Kvint S, Lindsten R, Magnusson A, Nilsson P, Bjerklin K. Autotransplantation of teeth in 215 patients. A follow-up study. *Angle Orthod* 2010;80:446-51.
 6. Almpani K, Papageorgiou SN, Papadopoulos MA. Autotransplantation of teeth in humans: A systematic review and meta-analysis. *Clin Oral Investig* 2015;19:1157-79.
 7. Amos MJ, Day P, Littlewood SJ. Autotransplantation of teeth: An overview. *Dent Update*. 2009;36:102-4, 107-10, 113.
 8. Tsukiboshi M. Autotransplantation of teeth: Requirements for predictable success. *Dent Traumatol* 2002;18:157-80.
 9. Plakwicz P, Wojtowicz A, Czochrowska EM. Survival and success rates of autotransplanted premolars: A prospective study of the protocol for developing teeth. *Am J Orthod Dentofacial Orthop* 2013;144:229-37.
 10. Kim E, Jung JY, Cha IH, Kum KY, Lee SJ. Evaluation of the prognosis and causes of failure in 182 cases of autogenous tooth transplantation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;100:112-9.
 11. Suzaki Y, Matsumoto Y, Kanno Z, Soma K. Preapplication of orthodontic forces to the donor teeth affects periodontal healing of transplanted teeth. *Angle Orthod* 2008;78:495-501.
 12. Lagerström L, Kristerson L. Influence of orthodontic treatment on root development of autotransplanted premolars. *Am J Orthod*. 1986 Feb;89(2):146-50.
 13. Andreasen JO, Paulsen HU, Yu Z, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part II. Tooth survival and pulp healing subsequent to transplantation. *Eur J Orthod* 1990;12:14-24.
 14. Denys D, Shahbazian M, Jacobs R, Laenen A, Wyatt J, Vinckier F, *et al.* Importance of root development in autotransplantations: A retrospective study of 137 teeth with a follow-up period varying from 1 week to 14 years. *Eur J Orthod* 2013;35:680-8.
 15. Czochrowska EM, Stenvik A, Album B, Zachrisson BU. Autotransplantation of premolars to replace maxillary incisors: A comparison with natural incisors. *Am J Orthod Dentofacial Orthop* 2000;118:592-600.
 16. Czochrowska EM, Stenvik A, Bjercke B, Zachrisson BU. Outcome of tooth transplantation: Survival and success rates 17-41 years posttreatment. *Am J Orthod Dentofacial Orthop* 2002;121:110-9.
 17. Watanabe Y, Mohri T, Takeyama M, Yamaki M, Okiji T, Saito C, *et al.* Long-term observation of autotransplanted teeth with complete root formation in orthodontic patients. *Am J Orthod Dentofacial Orthop* 2010;138:720-6.
 18. Kokai S, Kanno Z, Koike S, Uesugi S, Takahashi Y, Ono T, *et al.* Retrospective study of 100 autotransplanted teeth with complete root formation and subsequent orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2015;148:982-9.
 19. Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. *Br J Oral Maxillofac Surg* 1996;34:181-5.
 20. Paulsen HU. Autotransplantation of teeth in orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2001;119:336-7.
 21. Jonsson T, Sigurdsson TJ. Autotransplantation of premolars to premolar sites. A long-term follow-up study of 40 consecutive patients. *Am J Orthod Dentofacial Orthop* 2004;125:668-75.
 22. Schwartz O, Bergmann P, Klausen B. Resorption of autotransplanted human teeth: A retrospective study of 291 transplantations over a period of 25 years. *Int Endod J* 1985;18:119-31.
 23. Kristerson L, Lagerström L. Autotransplantation of teeth in cases with agenesis or traumatic loss of maxillary incisors. *Eur J Orthod* 1991;13:486-92.
 24. Kugelberg R, Tegsjö U, Malmgren O. Autotransplantation of 45 teeth to the upper incisor region in adolescents. *Swed Dent J* 1994;18:165-72.
 25. Cho JH, Hwang HS, Chang HS, Hwang YC. Application of orthodontic forces prior to autotransplantation - case reports. *Int Endod J* 2013;46:187-94.
 26. Andreasen JO, Paulsen HU, Zhijie Y, Ahlquist R, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part I. Surgical procedures and standardized techniques for monitoring healing. *Eur J Orthod* 1990;12:14-24.
 27. Andreasen JO, Paulsen HU, Yu Z, Bayer T. A long-term study of 370 autotransplanted premolars. Part IV. Root development subsequent to transplantation. *Eur J Orthod* 1990;12:38-50.
 28. Andreasen JO, Kristerson L, Andreasen FM. Damage of the Hertwig's epithelial root sheath: Effect upon root growth after autotransplantation of teeth in monkeys. *Endod Dent Traumatol* 1988;4:145-51.
 29. Barrientos S, Cardozo LA, Rojas LM. Autotrasplantes dentales: revisión sistemática de la literatura. *Univ Odontol*. 2012 Ene-Jun; 31(66): 133-143.
 30. Machado LA, do Nascimento RR, Ferreira DM, Mattos CT, Vilella OV. Long-term prognosis of tooth autotransplantation: A systematic review and meta-analysis. *Int J Oral Maxillofac Surg* 2016;45:610-7.
 31. Jang Y, Choi YJ, Lee SJ, Roh BD, Park SH, Kim E, *et al.* Prognostic factors for clinical outcomes in autotransplantation of teeth with complete root formation: Survival analysis for up to 12 years. *J Endod* 2016;42:198-205.
 32. Arikani F, Nizam N, Sonmez S. 5-year longitudinal study of survival rate and periodontal parameter changes at sites of maxillary canine autotransplantation. *J Periodontol* 2008;79:595-602.
 33. Tanaka T, Deguchi T, Kageyama T, Kanomi R, Inoue M, Foong KW, *et al.* Autotransplantation of 28 premolar donor teeth in 24 orthodontic patients. *Angle Orthod* 2008;78:12-9.
 34. Paulsen HU, Andreasen JO, Schwartz O. Pulp and periodontal healing, root development and root resorption subsequent to transplantation and orthodontic rotation: A long-term study of autotransplanted premolars. *Am J Orthod Dentofacial Orthop* 1995;108:630-40.