Tooth Autotransplantation as a Treatment Option: A Review

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Autotransplantation can provide patients with all the benefits of a natural tooth, but is seldom considered as a treatment option, in large part because of a lack of knowledge about periodontal tissue or the anatomy of teeth. The authors conducted a literature search using the PubMed database. They searched for key words including "autotransplantation," "clinical indications," "sequence and treatment procedures," "healing factors and prognosis" and "treatment options". Autotransplantation demonstrates as a viable treatment alternative, especially in growing adolescents. It provides a biological and economical treatment option for tooth replacement.

***Keywords**: Autotransplantation, clinical indications, healing factors, orthodontic treatment.*
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INTRODUCTION

Autotransplantation of teeth has been done for many years but with varying degrees of success. If the procedure is done with a full understanding of the applicable biological principles and if the proper clinical techniques are used, it can be very successful. Autotransplantation of teeth ensures maintenance of alveolar bone volume by physiological stimulation of the periodontal ligament (PDL).

Recently, autotransplantation has begun to gain attention again, most likely because research on PDL healing after autotransplantation has provided helpful information that can be applied to the procedure.[1,2]

Since the procedure causes bone and dental implant material to be fused together, the implant does not erupt along with adjacent teeth, so the placement of dental implants is contraindicated in young adolescent patients. Because of this, tooth autotransplantation, which maintains the PDL, will continue to be a suitable and attractive option in many cases for replacing missing units.

We conducted a search of the literature using PubMed as well as bibliographies from identified reviews relevant to our study. We selected clinical and scientific studies, literature reviews and case reports containing information about autotransplantation.

Indications for autotransplantation

Autotransplantation is defined as the transplantation of embedded, impacted or erupted teeth from one site into extraction sites or surgically prepared sockets in the same person.[3] Autotransplantation has been used to replace missing teeth and teeth of poor prognosis.[4-10]

The etiology of tooth agenesis is largely unknown. Vastardis[11] presented supporting evidence of a genetic etiology for tooth agenesis. He also reported the most frequently absent teeth are third molars followed by mandibular second premolars.[11] There are reports of associations of tooth agenesis and other congenital tooth anomalies to certain malocclusions.[12] The treatment plan for missing teeth cases should be based on a comprehensive evaluation of the age, occlusion, and space requirements of the patient as well as the size and shape of the adjacent teeth.[13] If extraction has been planned in the maxilla for the correction of crowding or reduction of a overjet, a maxillary premolar may be transplanted to the second premolar site in the mandible (Fig 1).

In most cases, the tooth or teeth to be extracted due to caries or periodontal disease are the first molars. In this case, transplantation of third molars to the first molar site may be considered.[4,6,10]

Maxillary incisors are the teeth most frequently involved in trauma. Zachrisson[14] reported autotransplantation of the developing mandibular second premolar to the avulsed maxillary incisors.

Autotransplantation may provide a simplified and faster treatment option for patients with ectopically positioned teeth. The optimal treatment for ectopically positioned

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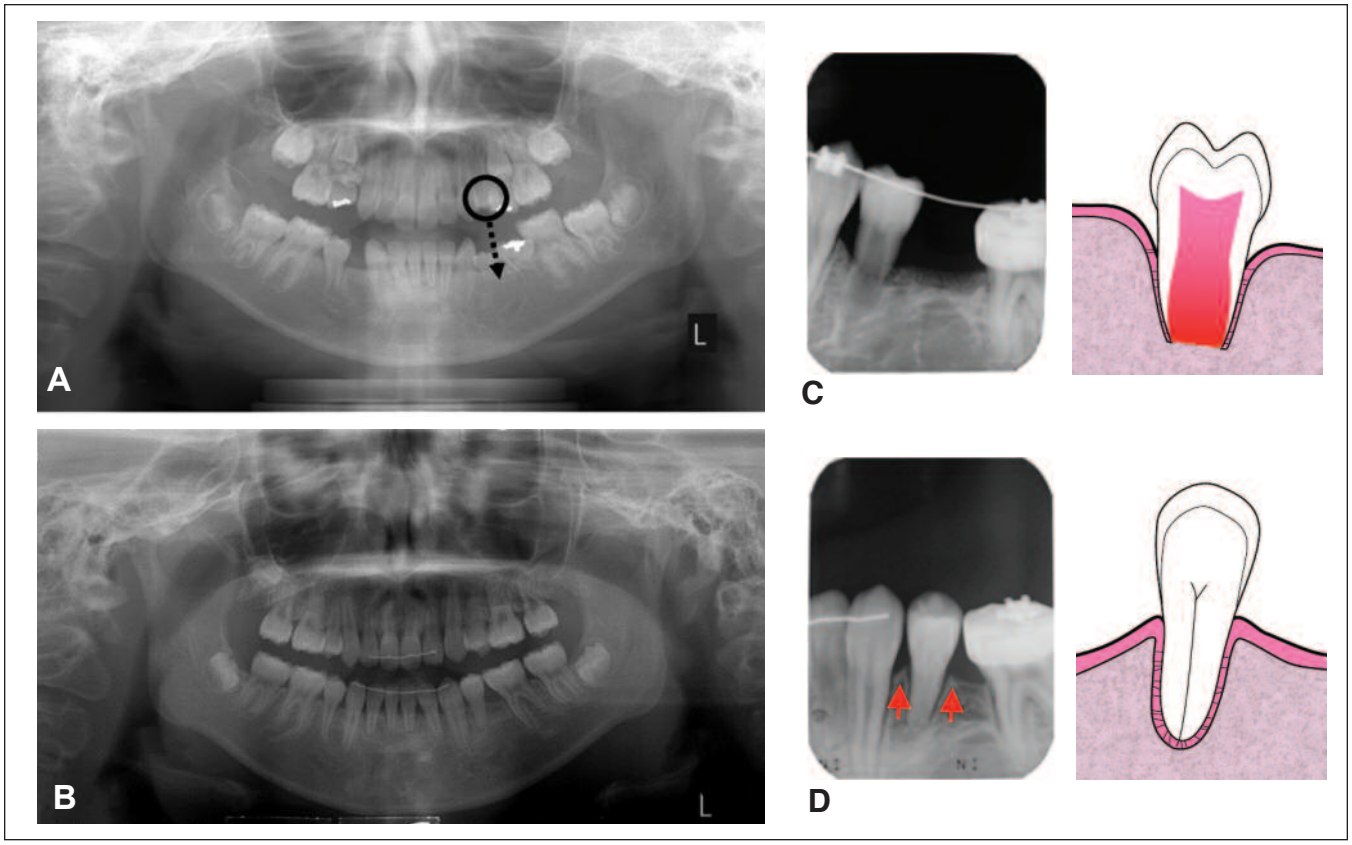

Figure 1. A. Panoramic radiograph of a 13-year-old girl with congenitally missing 3 mandibular premolars. The maxillary left first premolar was transplanted to the mandibular left premolar region. **B.** 2 years and 6 months after transplantation, the transplanted tooth shows partial pulp canal obliteration. The transplant responds normally to electric pulp testing (EPT). **C.** The donor tooth was transplanted when three fourths of the root was completed. **D.** There has been not only orthodontic rotation but also orthodontic movement to close space and as a result, apical root resorption has occurred. Alveolar bone and lamina dura have successfully developed and the transplant showed normal tooth mobility.

canines is surgical exposure and orthodontic treatment.[15] However, there are cases of severe ectopic position of maxillary canines in which transplantation should be a considered treatment alternative.[16]

In immature and developing teeth, root canal therapy is usually not necessary because the apex is open and revascularization of the pulp is expected. However, for the transplantation of fully developed teeth, root canal therapy is usually performed 2 weeks after transplantation.[17,18] A summary of indications for transplantation of immature teeth is presented in Table I.[17-38]

Sequence and treatment procedures

The sequence of autotransplantation includes clinical and radiographic examination, diagnosis, treatment planning, a surgical procedure, possible endodontic treatment, restorative treatment, and maintenance.

Timing of the tooth extraction from the recipient site should be carefully determined. If the tooth is extracted prior to the date of transplantation, transplantation should be performed as soon as possible.[31] If the mesiodistal recipient space is insufficient for the donor tooth, it will be necessary to plan orthodontic space generation prior to transplantation. When bone width is not sufficient buccolingually, an autogenous bone graft or green-stick fracture may be performed at the recipient site.[17,38]

The donor tooth needs to be tried into the prepared recipient site. Changing the direction of the donor tooth by rotating it 90° helps to find a better fit if the initial orientation is not possible. After try-in of the donor tooth in the recipient site, the fit of the gingival tissues around the donor teeth should be checked. The success of transplantation depends on the primary closure of the gingival around the donor tooth. The transplant is placed slightly below the occlusal plane and secured with a suture. Sutures are removed a week posttransplantation. Occlusal adjustment of the implanted tooth is usually done to eliminate the possibility of premature contacts.[17,38] Next, composite adhesives and the flexible stabilization wire can be used to connect the transplanted tooth to the adjacent teeth. A physiological splint may be used that will allow for some movement of the tooth whilst immobilizing it enough to allow healing. Allowing for some minor movement reduces the potential of ankylosis and adverse effects on the periodontal and pulpal healing of the tooth.[39,40] Chlorhexidine rinse and antibiotics should be prescribed for a week after the surgery but in order to have a desirable antibiotic level in the blood during and immediately after surgery, antibiotics should be taken orally a few hours prior to the procedure.[17]

The fixation can be removed 1 to 2 months after the

Table I. Indications for transplantation

Donor teeth	Recipient site	Indications and prognosis
Maxillary Premolars	**Agenesis sites (the mandibular second premolars)**	If maxillary premolars are to be extracted for orthodontic reason, they can be transplanted to the mandibular second premolar site. The high predictability of this procedure and its dependence on the state of root formation has been confirmed in several long-term studies.
Premolars **The first choices would be mandibular first and second premolars because of their root anatomy, and the second choice would be the maxillary second premolar. The maxillary first premolar is not recommended due to its divergent root.**	**Maxillary anterior region**	Could be considered in children with accidental tooth loss where implants are contraindicated because of continued alveolar bone growth. The transplanted teeth can be restored with composite or porcelain laminates. Long-term studies of transplants to the anterior region demonstrated favorable long-term results.
Third Molars	**The first or second molars**	Potential for severe dental caries, endodontic problems, or juvenile periodontitis. The donor should be removed from the socket atraumatically.
	Agenesis sites (the second premolar region)	Making an accurate evaluation of the mesiodistal distance of the recipient site is important. The outcome of third molar transplantation seems less favorable than premolar transplantations; however, 75% of transplants have been successful over a long period of time.

procedure. Root canal treatment (RTC) of a transplanted tooth should be initiated before the splint is removed, but whenever this is done, the transplanted tooth should already be stable. RCT is necessary in a fully developed donor tooth because healing of the pulp cannot be expected after apical closure. Following are the recommended procedures after completion of the transplant surgery: RCT, orthodontic treatment, and definitive restoration. Periodontal healing, root growth, and tooth eruption after transplantation should be monitored by radiographic examination. Active orthodontic treatment is initiated 3 to 9 months after periodontal healing but before pulp canal obliteration.[17,32-34]

A criteria for success in autotransplantation is summarized in Table II.[39-46]

Factors affecting success of autotransplantation

An optimal sequence would be to perform the extraction of the tooth from the recipient site on the same day that donor tooth is removed for transplantation. If, however, the tooth should be extracted from the recipient site earlier due to toothache, infection, or other reasons, then the transplantation should be scheduled as soon as possible within a 1 month time frame. As the time interval between extraction from recipient site and transplantation increases, more resorption of bone occurs at the recipient site and there will be less support for the donor tooth.[17,38]

Success factors of the transplantation of teeth will be the healing of the PDL, no progressive root resorption, healing of gingival tissue and alveolar bone, and healing of the pulp and continuation of root development.[17,31-34]

Table II. Criteria for success in autotransplantation

Categories	Criteria for success
Radiographic examination	- No evidence of progressive inflammatory root resorption - Normal PDL space width around the transplanted tooth - No disturbance in root development - Lamina dura - Healing of alveolar bone
Clinical examination	- Normal tooth mobility and normal tooth function - Gingival healing and no indication of marginal attachment loss, inflammation - Healing of dental pulp - No patient discomfort - Normal percussion sound
Histological examination	- The PDL fibers are aligned to perpendicular, not parallel, to the root and alveolar bone - However, without extraction, it is impossible to evaluate clinical cases histologically

Clinically, it appears that satisfactory healing takes place in transplanted teeth when there is no root resorption, a maintenance of PDL space, and apparently normal tooth mobility. In transplantation, usually the PDL fibers on the walls of the surrounding prepared sockets are absent. It must be recognized, however, that not only will the intact and vital PDL be attached to the root surface but also PDL attachment to the bony walls of recipient sockets plays an important role in healing.[17] It is desirable to extract a tooth with as much PDL attached to it as possible, even though the cementoblast layer by itself seems to be effective in preventing root resorption.[17,31-34,38]

For optimal healing, it is also important to consider the role of the PDL attached to the donor tooth in the formation of gingival tissue and alveolar bone. Healing of dental pulp and the continuation of root development are expected when a donor tooth is in the developing stages. Hertwig's epithelial root sheath (HERS) is present on developing teeth, and capillary vessels regenerate through this apical foramen while periodontal tissue inside of the epithelial root sheath proliferates into pulp canals.[38,47] When the dental pulp does not heal after transplantation of developing teeth, root canal therapy is necessary. Infection of dental pulp tissue is the primary reason of a transplant's failure to heal. Pulp healing can be monitored with either pulpal sensitivity or radiographic signs of pulp canal obliteration.[31,48] In most of the teeth transplanted in Moorrees tooth developmental stages 3 to 4, both events were observed and only a few teeth showed only one sign.[34,49] Although the transplanted tooth sometimes does not respond to electric pulp testing (EPT), endodontic treatment is generally not necessary. However, when the pulp obliteration is rapid (which in traumatology is defined as almost complete obliteration of the entire pulp chamber within a year), preventive endodontics might be safer than expectation, to avoid the risk for perforations later if periapical problems develop.[26]

The positive relationship between orthodontic treatment and surface resorption is to be expected when the known relationship between resorption and orthodontic therapy is considered.[49-51] Inadequate buccolingual width of the alveolar process can make it necessary to leave the transplant in a rotated position. Paulsen and colleagues[49] demonstrated orthodontic rotation induced a slight surface resorption and a significantly shorter tooth length, a mean of 1.2 mm. Furthermore, in their study a few cases showed a late pulp necrosis. The occurrence of pulp necrosis subsequent to orthodontic rotation could be related to a strangulation of the vascularization entering the apical foramen.

Attention must be paid during the plantation not to mechanically damage the periodontal ligament of the donor tooth by pushing it into the recipient site. Considering both healing of the dental pulp and continued development of roots, the ideal timing of transplantation of developing teeth is when the donor tooth roots are three fourths to four fifths completed.[17] Teeth with short root trunks tend to develop periodontal pockets in the furcation area after the transplantation. Multirooted teeth enamel projection or peridodontally involved teeth with attachment loss of more than one third of the roots are contraindicated.

A summary of factors contributing to successful autotransplantation is presented in Table III.[17,31-34,52-55]

Treatment options for congenitally missing teeth

Treatment options for adolescent patients with congenitally missing teeth are several, including the following: extraction of primary teeth which allows adjacent teeth to close the space spontaneously, retention of primary teeth if they are not anklyosed, extraction of deciduous teeth and closure of the space orthodontically, replacing the teeth with implants when facial growth is completed, the placement of fixed metal or ceramic prostheses, the placement of removable partial dentures, or the use resin-bonded fixed bridges.[26,39,56]

Retaining primary teeth is a possible option for aplasia.[57] Bjerklin and Bennett[57] report that the rate of resorption of primary teeth diminishes with age, and clinically no further root resorption is evident after age 20. As mentioned above, another alternative for patients with congenitally missing teeth is replacement with implants. In growing patients, however, implants impede normal growth of the alveolar process and are contraindicated.[58-60] For this reason, if implant replacement is the treatment option of choice, then lengthy space maintenance will be necessary (Table IV).[26,58-65] A conventional fixed bridge could also be used. In adolescents, preparation of the abutment teeth might need to be delayed due to pulp size and the necessity for lengthy space maintenance. Some disadvantages of removable partial dentures include their temporary nature and the need to replace them periodically during growth. Although a resin-bonded fixed bridge might be another option, it presents disadvantages, including the irreversible tooth preparation that is required and the uncertain longevity of this type of prosthesis.

Autotransplantation, which provides the possibility of a natural tooth rather than a prothesis or an osseointegrated implant to replace a missing tooth, is a unique treatment possibility in orthodontics of young patients. By means of this technique, a complicated treatment problem can be transferred to another site in the dental arch where it will be easier to solve orthodontically; however, there are some situations where autotransplantation is not immediately possible as a one-step procedure. In such cases, cryopreservation creates new possibilities when an extraoral storage period of months or years is needed to orthodontically prepare the recipient region.[38,66]

CONCLUSIONS

Autotransplantation of teeth offers a new treatment option for some clinical situations. It permits tooth movement to distant or opposite sides of the same dental arch, as well as to the opposite jaw. Furthermore, transplantation offers other potential benefits such as bone induction and the reestablishment of a normal alveolar process in addition to tooth replacement. Even if the transplant fails later, there is

Table III. Successful healing factors associated with autotransplantation of teeth

Categories	Influencing factors for prognosis
Patient related factors	- Better results in younger patients - A patient free of major systemic and metabolic problems or specific habits (e.g., smoking) - Good oral hygiene and a cooperative attitude
Donor tooth related factors	**Periodontal ligament (PDL)** - The presence of intact and vital PDL attached to the root surface - Preservation of vital PDL when the tooth is outside the mouth using physiologic salt water or milk or preservation liquids and as short a surgery time as possible - Enhanced healing of the gingival tissue by placing a 1 mm band of PDL fibers on the root above the crest of bone - A major factor in the formation of alveolar bone - A chance of inadequate PDL development as an effective attachment with an impacted tooth (nonfunctioning tooth) **Healing of dental pulp** - The preservation of Hertwig's epithelial root sheath (HERS) - Healing of the dental pulp occurs until Moorrees tooth development stage 5 - When the diameter of the apical foramina is > 1 mm, there is more than an 87% chance the dental pulp will heal **Continuation of root development** - Ideal timing of transplantation is when development of the donor tooth roots is 3/4 to 4/5 complete **Gingival adaptation** - Tight flap adaptation prevents bacterial invasion into the recipient socket **Root morphology** - Teeth with a single, cone-shaped root without concavity around the cervical area are most favorable
Recipient site related factors	- Bone width and height should be adequate to receive the donor tooth - Better healing can be expected if the PDL tissue is still attached - Transplantation should be performed the day of transplantation or within 1 month after extraction
Clinical factors	- Surgery should be performed by a clinician with experience in such areas as donor tooth extraction, preparation of the recipient site, and tissue management

Table IV. Factors in the choice of dental implant vs. autotransplantation

	Dental implant	Autotransplant
Patient age	After alveolar bone growth is completed	No patient age limit However, patients older than 40 have a better success rate when implant treatment has been used
Function and esthetics	Does not have a PDL No bone induction capacity Eruption is not possible, a disadvantage in growing patients Prosthetic treatment is required Nonadjustable The first choice for completely edentulous patients	Has a normal PDL, serving as a shock absorber and a proprioceptor Can promote bone formation Normal eruption is possible In some cases, prosthetic treatment is not required Adjustable position after surgery Needs an ideal donor tooth
Gingiva	A normal gingival contour is problematic, especially when 2 implants are adjacent to each other	A normal gingival contour can be induced
Orthodontic movement	Cannot be moved orthodontically However, can be used as an orthodontic anchorage device	Can be moved orthodontically
Time and cost	Needs an ossointegration stage before prosthodontic treatment More expensive	Needs fixation stage Less costly
Long-term results	Long-term follow-up studies (more than 15 years) are lacking	Transplanted teeth have been observed for up to 40 years and have similar healing rates

an intact recipient area that could be used for an implant. A prerequisite for this method, however, is a thorough knowledge of the factors that influence the long-term success rate. If done properly, this method may supplement and or be used as a viable treatment option in present day clinical practice.

REFERENCES

1. Suzaki Y, Matsumoto Y, Kanno Z, Soma K. Preapplication of orthodontic forces to the donor teeth affects periodontal healing of transplanted teeth. Angle Orthod, 78: 495–501, 2008.
2. Nayak BN, Wiltshire WA, Ganss B, Tenenbaum H, McCulloch CAG, Lekic C. Healing of periodontal tissues following transplantation of cells in a rat orthodontic tooth movement model. Angle Orthod, 78: 826–831, 2008.
3. Tanaka T, Deguchi T, Kageyama T, Kanomi R, Inoue M, Foong KWC. Autotransplantation of 28 Premolar Donor Teeth in 24 Orthodontic Patients. Angle Orthod, 78: 12–19, 2008.
4. Patel A, Brennan JA, Sandler PJ. Autotransplantation of an impacted third molar: an orthodontic case report. Dent Update, 31: 596–601, 2004.
5. Nishimura K, Amano S, Nakao K, Goto S. Orthodontic treatment including autotransplantation of a mature tooth. Angle Orthod, 79: 387–393, 2009.
6. Kitahara T, Nakasima A, Shiratsuchi Y. Orthognathic treatment with autotransplantation of impacted maxillary third molar. Angle Orthod, 79: 401–406, 2009.
7. Santos LL. Treatment planning in the presence of congenitally absent second premolars: a review of the literature. J Clin Pediatr Dent, 27: 13–18, 2002.
8. Fiorentino G, Vecchione P. Multiple congenitally missing teeth: Treatment outcome with autologous transplantation and orthodontic space closure. Am J Orthod Dentofacial Orthop, 132: 693–703, 2004.
9. Enacar A, Keser EI, Mavili E, Giray B. Facial Asymmetry case with multiple missing teeth treated by molar autotransplantation and orthognathic surgery. Angle Orthod, 74: 137–144, 2004.
10. Lim WH, Chun YS. Orthodontic treatment combined with autotransplantation after removal of ameloblastoma. Am J Orthod Dentofacial Orthop, 135: 375–379, 2009.
11. Vastardis H. The genetics of human tooth agenesis; new discoveries for understanding dental anomalies. Am J Orthod Dentofacial Orthop, 117: 650–656, 2000.
12. Basdra EK, Kiokpasoglou MN, Komposch G.. Congenital tooth anomalies and malocclusions: a genetic link? Eur J Orthod, 23: 145–151, 2001.
13. Kokich VG, Kokich VO. Congenitally missing mandibular second premolars: clinical options. Am J Orthod Dentofacial Orthop, 130: 437–444, 2006.
14. Zachrisson BU. Planning esthetic treatment after avulsion of maxillary incisors. J Am Dent Assoc, 139: 1484–1490, 2008.
15. Bedoya MM, Park JH. A review of diagnosis and management of impacted maxillary canines. J Am Dent Assoc, 140: 1485–1493, 2009.
16. Arikan F, Nizam N, Sonmez S. 5-year longitudinal study of survival rate and periodontal parameter changes at site of maxillary canine autotransplantation. J Period, 79: 595–602, 2008.
17. Tsukiboshi M. Autotransplantation of teeth. Quintessence, Tokyo; 10–181, 2001.
18. Amos MJ, Day P, Littlewood SJ. Autotransplantation of teeth: an overview. Dent Update, 36: 102–113, 2009.
19. Lai FS. Autotransplantation of an unerupted wisdom tooth germ without its follicle immediately after removal of an impacted mandibular second molar: a case report. J Can Dent Assoc, 75: 205–208, 2009.
20. Northway W. Autogenic dental transplants. Am J Orthod Dentofacial Orthop, 121: 592–593, 2002.
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, 125: 668–675, 2004.
22. 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, 118: 592–600, 2000.
23. Jang KT, Kim JW, Lee SH, Kim CC, Hahn SH, García-Godoy F. Reposition of intruded permanent incisor by a combination of surgical and orthodontic approach: a case report. J Clin Pediatr Dent, 26: 341–346, 2002.
24. Ulusoy AT, Akkocaoglu M, Akan S, Kocadereli I, Cehreli ZC. Reimplantation of an inverted maxillary premolar: case report of a multidisciplinary treatment approach. J Clin Pediatr Dent, 33: 279–282, 2009.
25. Rao J, Fields HW, Chacon GE. Case report: autotransplantation for a missing permanent maxillary incisor. Pediatr Dent 30: 160-166, 2008.
26. Zachrisson BU, Stenvik A, Haanæs HR. Management of missing maxillary anterior teeth with emphasis on autotransplantation. Am J Orthod Dentofacial Orthop, 126: 284–288, 2004.
27. Park NJ, Oh HS, Choi WJ, Lee WH, Min BJ, Hong KJ. Case report of autotransplantation of immature teeth. J Korean Assoc Maxillofac Plast Reconstr Surg, 26: 110–115, 2004.
28. Dermaut LR, Verrue V, Pauw GD. Transplantation after upper incisor trauma. A case report. Am J Orthod Dentofacial Orthop, 105: 425–429, 1994.
29. Paulsen HU. Autotransplantation of teeth in orthodontic treatment. Am J Orthod Dentofacial Orthop, 119: 336–337, 2001.
30. Wu TY, Yang SF, Kuang SH, Wu CH. Treatment of a child with 4 congenitally missing maxillary premolars by autotransplantation and orthodontic intervention: a case report. J Oral Maxillofac Surg, 67: 450–456, 2009.
31. Andreasen JO, Paulsen HU, Yu Z, 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, 12: 3–13, 1990.
32. 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, 12: 14–24, 1990.
33. Andreasen JO, Paulsen HU, Yu Z, Schwartz O. A long-term study of 370 autotransplanted premolars. Part III. Periodontal healing subsequent to transplantation. Eur J Orthod, 12: 25–37, 1990.
34. 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, 12: 38–50, 1990.
35. Lundberg T, Isaksson S. A clinical follow-up study of 278 autotransplanted teeth. Br J Oral Maxillofac Surg, 34: 181–185, 1996.
36. Stenvik A, Zachrisson BU. Orthodontic closure and transplantation in the treatment of missing anterior teeth. An overview. Endod Dent Traumatol, 9: 45–52, 1993.
37. Kriseterson L, Lagerström L. Autotransplantation of teeth in cases with agenesis or traumatic loss of maxillary incisors. Eur J Orthod, 13: 486–492, 1991.
38. Andreasen JO. Atlas of replantation and transplantation of teeth. W.B. Saunders, Philadelphia; 58–288, 1992.
39. Oskar Bauss, Rainer Schwestka-Polly, Reinhard Schilke, Stavros Kiliaridis. Effect of different splinting methods and fixation periods on root development of autotransplanted immature third molars. J Oral Maxillofac Surg, 63: 304–310, 2005.
40. Pogrel MA. Evaluation of over 400 autogenous tooth transplants. J Oral Maxillofac Surg, 45: 212–216, 1987.
41. Tsukiboshi M. Autotransplantation of teeth: requirement for predictable success. Dent Traumatol 18: 157–180, 2002.
42. Andreasen JO, Kristerson L. The effect of limited drying or removal of the periodontal ligament. Periodontal healing after replantation of mature incisors in monkeys. Acta Odontol Scand, 39: 1–13, 1981.
43. 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, 100: 112–129, 2005.
44. Raghoebar GM, Vissink A. Results of intentional replantation of molars. J Oral Maxillofac Surg, 57: 240–244, 1999.

45. Cohen AS, Shen T.C, Pogrel MA. Transplanting teeth successfully: autografts and allografts that work. J Am Dent Assoc, 126: 481–485, 1995.
46. Thomas S, Turner SR, Sandy JR. Autotransplantation of teeth: is there a role? Br J Orthod, 25: 275–282, 1998.
47. Day PF, Kindelan SA, Spencer JR, Kindelan JD, Duggal MS. Dental trauma: part 2. Managing poor prognosis anterior teeth – treatment options for the subsequent space in a growing patient. J Orthod, 35: 143–155, 2008.
48. Andreasen FM, Andreasen JO. Diagnosis of luxation injuries: the importance of standardized clinical, radiographic and photographic techniques in clinical investigations. Endod Dent Traumatol, 1: 160–169, 1985.
49. 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, 108: 630–640, 1995.
50. Linge BO, Linge L. Apical resorption in upper anterior teeth. Eur J Orthod, 5: 173–183, 1983.
51. Lagerström L, Kristerson L. Influence of orthodontic treatment on root development of autotransplanted premolars. Am J Orthod, 89: 146–149, 1986.
52. 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, 121: 110–119, 2002.
53. Mine K, Kanno Z, Muramoto T, Soma K. Occlusal forces promote periodontal healing of transplanted teeth and prevent dentoalveolar ankylosis: an experimental study in rats. Angle Orthod, 75: 637–644, 2005.
54. Aslan BI, Üçüncü N, Doğan A. Long-term follow-up of a patient with multiple congenitally missing teeth treated with autotransplantation and orthodontics. Angle Orthod, 80: 396–404, 2010.
55. Motegi E, Takane Y, Tokunaga E, Sueishi K, Takano N, Shibahara T, Saito C. Six-year follow-up in skeletal class III patient aged over 40 receiving orthognathic surgery and autotransplantation: a case report. Bull Tokyo Dent Coll, 50: 141–147, 2009.
56. Kokich VG, Crabill KE. Managing the patient with missing or malformed maxillary central incisors. Am J Orthod Dentofacial Orthop, 129: S55–S63, 2006.
57. Bjerklin K, Bennett J. The long-term survival of lower second primary molars in subjects with agenesis of the premolars. Eur J Orthod, 22: 245–255, 2000.
58. Westwood RM, Duncan JM. Implants in adolescents: a literature review and case reports. Int J Oral Maxillofac Implants, 119: 750–755, 1996.
59. Odman J, Grondahl K, Lekholm U, Thilander B. The effect of osseointegrated implants on the dentoalveolar development (a clinical and radiographic study in growing pigs). Eur J Orthod, 13: 279–286, 1991.
60. Thilander B, Odman J, Grondahl K, Lekholm U. Aspects of osseointegrated implants inserted in the growing jaws: a biometric and radiographic study in the young pig. Eur J Orthod, 14: 99–109, 1992.
61. Lindh T, Gunne J, Tillberg A, Molin M. A meta-analysis of implants in partial edentulism. Clin Oral Impl Res, 9: 80–90, 1998.
62. Paulsen HU, Andreasen JO. Eruption of premolars subsequent to autotransplantation. A longitudinal radiographic study. Eur J Orthod, 20: 45–55, 1998.
63. Thilander B, Ödman J, Gröteborg K, Friberg B. Osseointegrated implants in adolescents. An alternative in replacing missing teeth? Eur J Orthod, 16: 84–95, 1994.
64. Frenken JW, Baart JA, Jovanovic A. Autotransplantation of premolars. A retrospective study. Int J Oral Maxillofac Surg, 27: 181–185, 1998.
65. Paulsen HU, Shi X-Q, Welander U, Huggare J, Scheutz F. Eruption pattern of autotransplanted premolars visualized by radiographic color-coding. Am J Orthod Dentofacial Orthop, 119: 338–345, 2001.
66. Laureysa W, Beeleb H, Cornelissenc R, Dermauta L. Revascularization after cryopreservation and autotransplantation of immature and mature apicoectomized teeth. Am J Orthod Dentofacial Orthop, 119: 346–352, 2001.