

Transplanting Molars

Autotransplantation of two third molars to first-molar sites, with a 13-year follow-up

Short course description

Tooth autotransplantation involves the extraction and replacement of a donor tooth from its original position and its replantation to a recipient site. Autotransplantation can be a suitable treatment option, particularly in younger patients, after careful clinical and radiographic examination and proper treatment planning.



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Abstract

For patients in whom a tooth is congenitally missing or lost to caries or trauma and when an appropriate donor tooth is available to fill the space, autotransplantation can be a predictable procedure that has been employed worldwide for more than 50 years with great success. Autotransplantation relocates one's own tooth from its original position to another site. This recipient tooth site could have a tooth treatment-planned for extraction or may be a recent extraction site, or could be an edentulous site, or the site of a congenitally missing tooth.

This article discusses the advantages and disadvantages of autotransplantation (AT); its treatment planning; a detailed sequence of the clinical procedure; and the criteria for the procedure's success both pre- and postoperatively. With this information, clinicians should be able to add a successful treatment option for unrestorable or missing teeth, particularly in growing (pediatric and adolescent) patients who do not yet have the option for implant placement.

Educational objectives

After reading this article, the participant should be able to:

1. Appropriately identify and treatment-plan potential autotransplantation cases.
2. Successfully sequence and perform autotransplantations with predictable success.
3. Educate other dental care providers and patients about this alternative treatment option.
4. Add a successful treatment option for unrestorable or missing teeth, particularly in patients who do not have the option for implant placement.

Introduction

Tooth autotransplantation involves extracting a donor tooth from its original position to replant it in a recipient site. Provided that an appropriate donor tooth is available to fill the space, autotransplantation can treat patients who:

- Have a congenitally missing tooth (agenesis) or one lost to caries or trauma (edentulous).
- Have a recently extracted tooth or one treatment-planned for such.

A third molar could be extracted from its socket, for example, to be donated to another site where a tooth has been deemed unrestorable and will be extracted. Or, an edentulous site might receive a tooth that had been treatment-planned for extraction, perhaps because of orthodontic/crowding purposes.

Disclosure:

The author declares that in the past 12 months, she has had a financial interest, arrangement or affiliation within the field of dentistry or health care with the following: employee of Hopkinton Endodontics; owner of McIntyre Endodontics.

Case study

A 21-year-old patient, with a history of smoking but otherwise healthy, presented to the Emergency Student Dental Clinic with a chief complaint of pain in her lower left quadrant. A periapical radiograph (Fig. 1) showed an extensive amalgam restoration on Tooth #19 and radiolucencies around both roots. Pulp vitality testing and a clinical exam confirmed the diagnosis: necrotic pulp with symptomatic apical periodontitis, significant periodontal probings, and a distal amalgam overhang. After a discussion of treatment and financial options, the tooth was deemed unrestorable and scheduled for extraction the next day because of the patient's pain and discomfort.

Before she left, a panoramic radiograph (PAN) was taken; the patient's maxillary third molars, with approximately two-thirds root formation, were noted as potential donors for AT (Fig. 2). Because finances were of great concern for the patient, this treatment solution seemed to be the leading alternative.

Of importance: If the patient's discomfort and pain could have been controlled with pulpal/intracanal debridement and disinfection, anti-inflammatory medications or acetaminophen, and perhaps an antibiotic, it would have been preferable to avoid extracting #19 the following day and, rather, plan for it closer to the date of the autotransplantation procedure—best that same day—to ensure the recipient periodontal ligament (PDL) cells were of highest viability. A same-day extraction and autotransplantation placement is referred to as a *one-stage autotransplant procedure*.^{1,2} Because the patient was in great pain and with inflammation and radiolucencies—a very acidic environment in which to place a donor transplant tooth—the extraction of #19 occurred earlier and we began planning for the autotransplantation of tooth #1 to be moved to the site of #19. (This type of sequence is referred to as a

two-stage autotransplant procedure when done within 6 weeks of extraction.^{1,2})

Although cone beam computed tomography (CBCT) was available to us in 2004, it was not employed for this case. It is now highly recommended,²² to more reliably measure all donors and recipient sites. The PAN was studied further and generalized caries was noted; a subsequent appointment to take a full-mouth series was made. Figs. 3a–d show the periapical and bitewing images from the series.

After studying the PAN, it was clear that the interseptal bone that remained between mesial and distal roots of #19 (Figs. 1 and 2) would need to be removed to accommodate #1. Both the amount of this bone to be removed and #1's approximate root length were obtained from the PAN. Because #1 was not clinically visible—not yet erupted (Fig. 4a)—and its crown could not be measured clinically, the crown width was measured from the PAN (not exact), while the mesial–distal (M–D) width of the #19 site could be measured directly (Figs. 4b and 4c). Because #19 had a greater M–D width than the crown width of #1, a rotation of approximately 90 degrees was planned of #1 to maximize its M–D width in its new location. (This is common in practice and recommended.^{1,2,13,19})

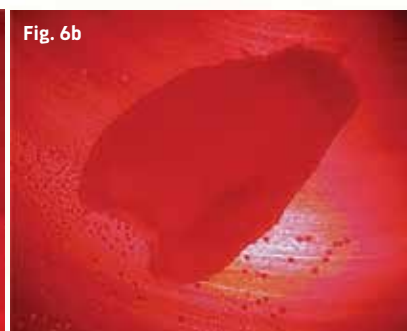
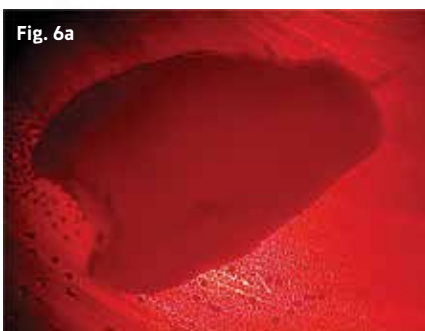
Three days before the autotransplantation procedure (Table 1), the patient began using a 0.12 percent chlorhexidine (CHX) rinse three times a day and 100mg of doxycycline twice a day: standard preoperative protocol.^{1–5} Ultimately, it would be 20 days after her initial presentation with pain, and 19 days after the extraction of #19, that the procedure to move #1 to the now-edentulous #19 site began.

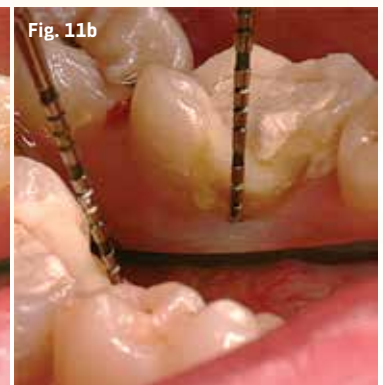
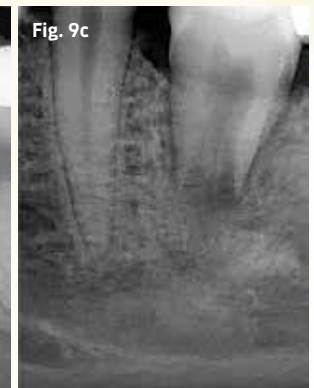
The first autotransplantation case

Before the procedure, the patient was asked to swish and rinse with 2 percent chlorhexidine.^{1–4} Profound local anesthesia at #19 was achieved with lidocaine. Because the tissue had begun to heal over the #19 recipient site (Figs. 4b and 4c), a full-thickness mucoperiosteal flap was reflected. The interseptal bone was removed (Fig. 5) using a large (size 8), slow-speed, round-carbide surgical-length bur.^{6,12} The oral surgeon expeditiously removed #1 with the forceps solely touching the clinical crown of the tooth—caution was taken to avoid the PDL on the root surface—and it was immediately placed in a tissue storage medium, Hank's Balanced Salt Solution (HBSS) with phenol red (Figs. 6a and 6b).^{1,2,7–10} The Hertwig's epithelial root sheath (HERS)—an important component for AT success^{1,2,5,6}—of #1 was clearly visible

Table 1
Pre- and postoperative management ^{1,2,5,12,13,20}

- Chlorhexidine rinse TID: 3 days prior and 10 days postop.
- Doxycycline 100mg BID: 3 days prior and 7 days postop.
- NSAID premedicate 1 hour preoperatively and QID postop as needed.
- Meticulous oral hygiene.
- No smoking.
- Soft diet for 10 days. ^{3,4}





with an opening greater than 3mm. The total extraoral dry time was less than 1 minute, and the time #1 was in the HBSS was no more than 2 additional minutes; therefore, total EO time was less than 3 minutes and the extraoral dry time was less than 1 minute; these are ideal scenarios.^{1,2,10,11} Held only by the clinical crown, #1 was then gently placed into the prepared recipient socket at site #19.

The entire donor tooth fell almost entirely into the prepared socket, leaving only 1–2mm of clinical crown supragingival (Fig. 7a, p. 73). Nevertheless, the tooth was securely in the site, albeit subgingival. Because the patient had a very deep bite (Fig. 7b, p. 73), the fact that the tooth was completely out of occlusion was likely optimal. Sutures of 4-0 Vicryl further secured the reflected flap around the donor tooth; a purse-string was created and the entire gingiva was wrapped to envelop the tooth. This likely was also advantageous, because it decreased bacterial contamination down the crevicular sulcus.^{1,2,6} After the surgery, the buccal and lingual cortical plates were compressed and the mucosa reapproximated with CHX-soaked gauze. The patient was given both verbal and written postoperative instructions, and was dismissed while still biting gently at the site on the CHX gauze, which she was told to remove after 15 minutes.¹²

After one week, the patient returned and a new periapical image (PA) of the new “#19” was taken (Fig. 8). Any PA is indicated within the 4-week follow-up visit.^{1–4, 13, 20} The clinical exam revealed no significant findings, although periodontal probings and percussion tests were intentionally avoided. The satisfied patient reported no pain or discomfort, and sutures were removed.

Three months later, several angulated periapical radiographs of the new #19 were exposed—the first time a PDL can be appreciated (Fig. 9a); a PDL is expected to be visualized by the 2-month PA. At the clinical examination, pulp vitality tests (PVTs), including periodontal probings and percussion, were within normal limits. Meanwhile, the patient became a patient of record at the dental school and began her restorative treatment plan; she initiated root canal therapy on #30 in June 2004, about 4 months after initially presenting.

Six months after the AT procedure, another periapical radiograph of #19 was taken (Fig. 10); continued PDL and bony fill can be appreciated.

The second autotransplantation case

About 9 months after the first AT procedure,

while #30 was temporized, the ML cusp fractured subgingivally and was deemed unrestorable (Figs. 11a and 11b). Another AT of #16 (Fig. 12) to site #30 was planned. The same pre-, peri- and postprocedural protocols were closely followed, with few exceptions. For tooth storage medium,^{7–10} HBSS *without* phenol red was available. Figs. 13a and 13b show #16 with HERS and an open apex of about 2mm.^{1,2,5} Less interseptal bone was removed at the recipient site during this procedure. The donor tooth fit well and no additional adjustments were needed. During this procedure, a splint, as well as sutures, (Figs. 14a–e) were employed to ensure stability. Once again, there was negligible extraoral dry time, and total extraoral time (even in the HBSS) was similar to that described in the first procedure.

As suggested for follow-up protocol^{1–4,12–15} as seen in Table 2, one week later the patient was evaluated and a PA of the new “#30” was taken (Fig. 15a, p. 77). At this visit, the splint and sutures were removed. The clinical exam revealed no significant findings; periodontal probings and percussion were intentionally avoided.^{1,2} The patient reported no pain or discomfort and was satisfied. The greater remaining interseptal bone and the defined PDL that remained in this one-stage AT procedure in both the mesial and distal root outlines can be seen radiographically. Clinically, #19 also appeared within normal limits at its 9-month follow-up (Fig. 15b, p. 77).

Table 2
Follow-up schedule^{1–4,13,20}

- 1–2 weeks, 1 month, 2 months, 3 months, 6 months, 12 months, then yearly for 5 years. If root formation not yet complete at 1 year, 2-year follow-up becomes more critical.^{12,13,20}
- PVTs should be remarkable by the 6-month follow-up appointment.^{1,2}
- PAs at each visit, because adverse sequelae could become evident as early as 4 weeks¹² and normal PDL may be detected at the 8-week radiograph.^{11,15,20}
- IRR tends to start as early as 4 weeks and can be detected around the 2-month radiograph, while RRR tends to start as early as 6–8 weeks but unfortunately tends to be noticed between the 6-month and 1-year radiographs.^{1,2,11,12,15,20}
- Endodontics best within 2–4 weeks if closed apex.^{1,2,12}
- Orthodontics best at 6 months or longer.^{3,4,13,24–27}

Follow-ups from 1 month to 13 years

- About 1 month later, another PA of the new #30 revealed no PDL but some bony fill was evident (Fig. 16).
- About 3 months after the AT procedure for #30, a new PA reflected continued success (Fig. 17a) with a PDL appearing. For #19, at approximately 11 months post-AT, all bony fill appeared to be complete from the original socket (Fig. 17b). At that time, #19 had also erupted more into occlusion. Clinical exam and all PVTs, including periodontal probings and percussion, were within normal limits for both teeth.
- About 6 months after the #30 AT, clinical pictures were obtained for both teeth (Figs. 18, 19a and 19b). The splint that had been employed for #30, in addition to the 90-degree rotation^{1,2,13,19} of the new #30, maximized the M–D width and adjacent interproximal contacts. Conversely, #19 did not employ a splint; its created socket was much bigger, likely accounting for the less-than-ideal position as it erupted into occlusion (Figs. 19a and 19b): slightly rotated and light interproximal contacts. While #19 was still functional and healthy, clearly the #30 position is more ideal. Overall, 14 months after AT of #19, its periapical (Fig. 19c) reflects success as apical root formation continued, surrounding bone has healed and, more importantly, horizontal bone is evident both mesially and distally around the cementoenamel junction (CEJ).
- About 9 months after the second AT procedure, the new #30 appeared to have complete healing of the bony socket, despite some original PDL still evident, with horizontal bone also at its CEJ and continued root development with apical pulp canal obliteration slightly evident (Fig. 20a, p. 78). For #19, now 1.5 years after its AT, two PAs were exposed: one without a bite stent (Fig. 20b, p. 78) and, now that the tooth was in full occlusion, one with a bite stent (Fig. 20c, p. 78) so that future radiographs could be easily reproduced once the tooth was in occlusion and stable. On #19, pulp canal obliteration (PCO)¹³ is evident throughout the entire pulp chamber, a clear PDL is traceable and bone has completely healed around the new root as well as horizontally to its CEJ. At this visit, as in all previous ones, the patient denied any symptoms, pain or discomfort and enjoyed the functional feeling

of being without a space. PVTs—palpation, percussion and probing—were all within normal limits for both teeth. While #30 had a normal positive response to cold, #19 was nonresponsive to cold, which is expected with PCO; as such, both #19 and #30 were responsive to electric pulp testing (EPT). In time, the patient completed the caries control and restorative phase of her treatment plan.

- Thirteen years after both ATs, the patient agreed to present to an endodontic colleague in private practice near the patient's home. The PAs that were taken (Figs. 21a and 21b, p. 78) reflected success in terms of surrounding socket and horizontal bone and in occlusion/function. Both teeth reflected full bone growth and restoration in all dimensions; both PDLs were fully traceable and without any signs of any resorptive defects, with continued and complete root development to an apical foramen, and both with complete pulp canal obliteration—a sign of pulpal health.^{1,2,13} The patient was in full capacity enjoying form and function, and again denied any symptoms, pain or discomfort. PVTs were performed: palpation, percussion and probing were all within normal limits. Cold response was negative on both teeth; EPTs were positive on both #19 and #30.

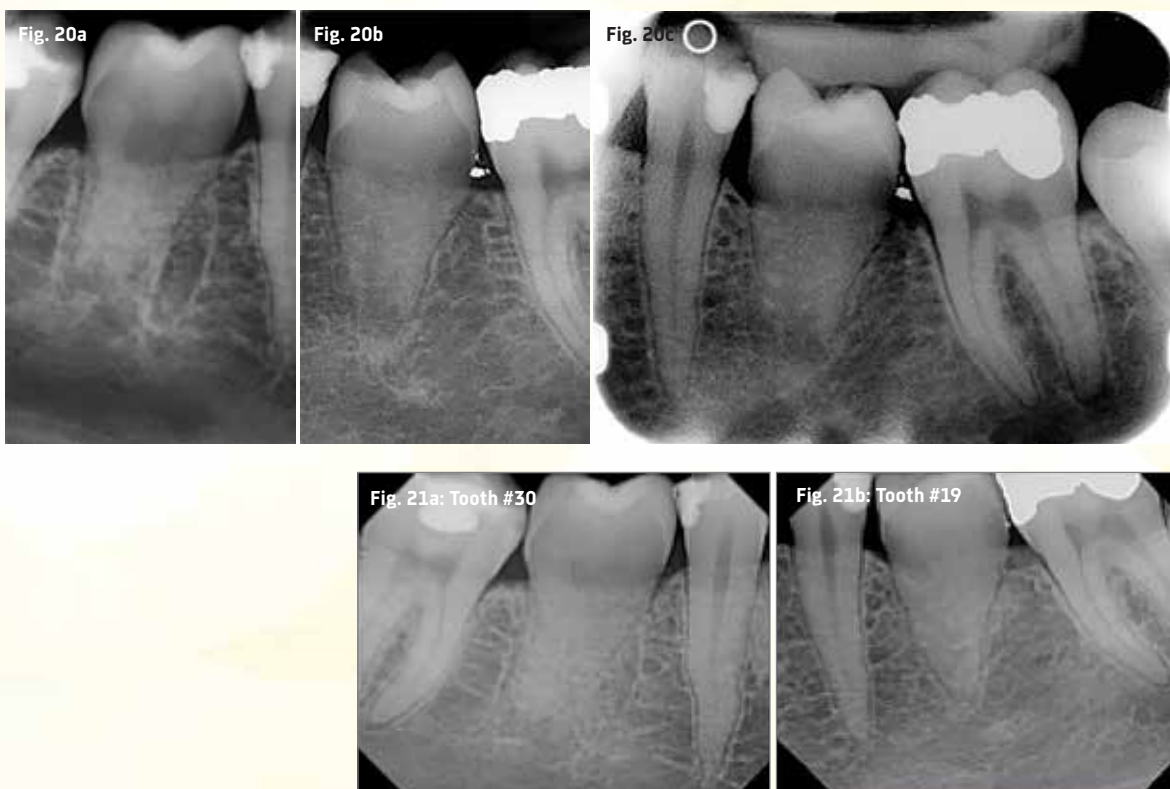
Discussion

Dental literature about autotransplantation began appearing more than 50 years ago.¹⁶ In recent years, authors such as Tsukiboshi,^{1,2} Andreasen,^{5,6,12–15} Cohen¹⁷ and others^{19,21,22} have provided much insight and enthusiasm regarding autotransplantation. Their case reports and publications have been extremely valuable resources for practitioners, whereby this treatment modality is shown to have predictable and repeated success. Nevertheless, while AT is more common in Asia, Europe and Scandinavia, perhaps because of logistics and more cross-specialty collaboration, in the United States it remains a limited treatment modality for many practitioners.

Advantages of AT

- The patient and practitioner can use natural tooth structure. In cases where premolar or third-molar extraction will be inevitable, this is particularly beneficial. Furthermore, while fixed bridges or resin bridges are valid alternatives in still-growing patients, AT avoids the preparation of adjacent teeth, which is even more valuable





when the teeth are intact. Many times, restorative procedures can be avoided altogether, which saves cost and time. AT can be a cost-effective alternative compared with other treatment options—for both children and adults.

- AT is less invasive than other surgical or implant procedures. It's also immediate, unlike most implant procedures that can take anywhere from 6 months to 2 years to complete in function.
- Of continued benefit also is the potential in autotransplanted teeth for continued root development and for bone induction and preservation, which is of utmost importance for growing patients. If an implant is needed later, and also for continued, symmetrical bone growth around the recipient site and its adjacent teeth, AT offers a priceless advantage over fixed/resin bridges, which permit the bone to atrophy. Bone loss and atrophy in growing patients may not be treatable later, when growth and development

has completed, leaving significant osseous defects, aesthetic obstacles or both. Premature extraction of a tooth during development might create an environment in which an implant would be unfeasible later because of resorbed bone. Maintenance and further formation of alveolar bone width and height during growth is invaluable; an autotransplanted tooth allows for both, unlike other restorative options such as fixed bridge.

Disadvantages of AT

- When compared with a simple extraction, the procedure can be more extensive, especially if the recipient site requires surgical preparation.
- Future complications may include ankylosis (replacement root resorption), surface or inflammatory root resorption, and/or loss of gingival attachment.^{1,2,5,15} Any of these adverse sequelae may result in loss of the transplanted tooth.
- An additional consideration includes patient management in very young

or uncooperative patients during a surgical procedure.

Case selection

The criteria for success in autotransplantations are well-established. Of utmost importance is a healthy periodontal ligament (PDL) on the transplanted tooth.¹⁵ If the PDL also remains at the recipient site, then the success rate will be additionally higher.^{1,2,23} The less complicated the root morphology of the transplanted tooth, also the better the prognosis.^{1,2} Patients younger than 40 show higher tooth-survival rates, even without residual PDL at the recipient site.^{1,2} In patients 40 and older, autotransplantation to healed edentulous sites, where the recipient socket must be prepared, reflect less long-term prognosis.^{1,2}

Criteria for success

Tsukiboshi outlines four criteria for autotransplantation success^{1,2}:

1. Healthy periodontal ligaments

Any periodontal disease, loss of attachment, ankylosis/resorption or a history of

trauma on an AT donor tooth decreases PDL health, resulting in a lower prognosis. The same applies for the PDL at the recipient site. However, donor PDL is more critical than recipient PDL.^{1,2}

Many teeth that might be removed (at the recipient site) for an AT tooth might already have a periapical radiolucency. This is less than ideal, but can be overcome with gentle curettage and a two-stage AT procedure, allowing some time between extraction at the recipient site and removal and transplantation of the donor tooth. Previous apical infection and inflammation in the recipient site can result in a successful AT procedure and a favorable long-term outcome (as presented in this case).

When there is residual PDL at the recipient site, there is a greater chance of success than if there is no PDL at the recipient site (as in agenesis sites).^{1,2,6,11–15} Akin to this is the ectopic donor. When a donor comes from an ectopic site (impacted canines, for instance), the likelihood of the donor PDL being damaged¹⁵ during its retrieval is likely, and hence, ectopic donors have less success when compared to their [more] superficial counterparts.^{6,15}

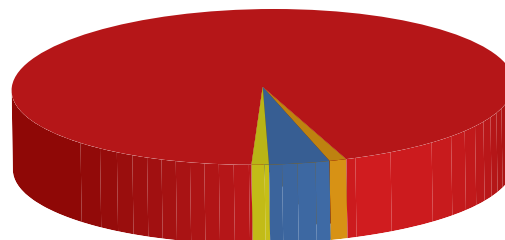
Graph A^{1,2} illustrates that when autotransplantation to extraction sockets with residual PDL occurs, normal healing occurs 94 percent of the time, while inflammatory root resorption (IRR) and surface root resorption (SRR) each occurred 1 percent of the time. No attachment gain resulted in only 4 percent of cases. Overall, the survival of these teeth was 100 percent, because all of them were still in place, but the true success of these teeth was 95 percent, because root resorption and lack of attachment will eventually lead to failure.

Graph B^{1,2} illustrates that autotransplantation to non-extraction sockets (without an existing PDL) results in lower success.^{1,2,6,11–15} Normal healing was found to occur 79 percent of the time, and surface root resorption occurred in 4 percent of cases. IRR and no attachment gain occurred in 6 percent of cases, and replacement root resorption (RRR), also known as ankylosis, occurred in 5 percent of the cases. Overall, the survival of these teeth was 100 percent, because all of them were also still in place, but the true success of these teeth was 83 percent. With more adverse sequelae in these cases—the three types of resorption and lack of attachment—more of these teeth will eventually fail.

2. Stage of root development

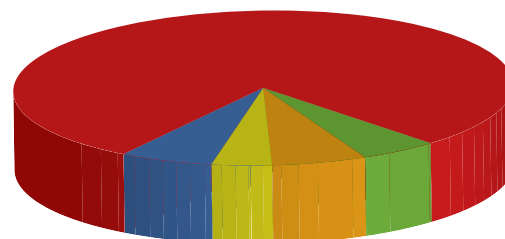
In this case, the patient was 21 years old—ideal regarding the stage of development of the third molars.

Graph A:
**Prognosis of transplantation to
extraction socket with existing PDL**



100%	Survival	94%	Normal healing
95%	Success	1%	Surface resorption
		4%	No attachment gain
		1%	Inflammatory resorption

Graph B:
**Prognosis of transplantation
to non-extraction sockets**



100%	Survival	79%	Normal healing
83%	Success	4%	Surface resorption
		6%	Inflammatory resorption
		5%	Replacement resorption
		6%	Attachment loss

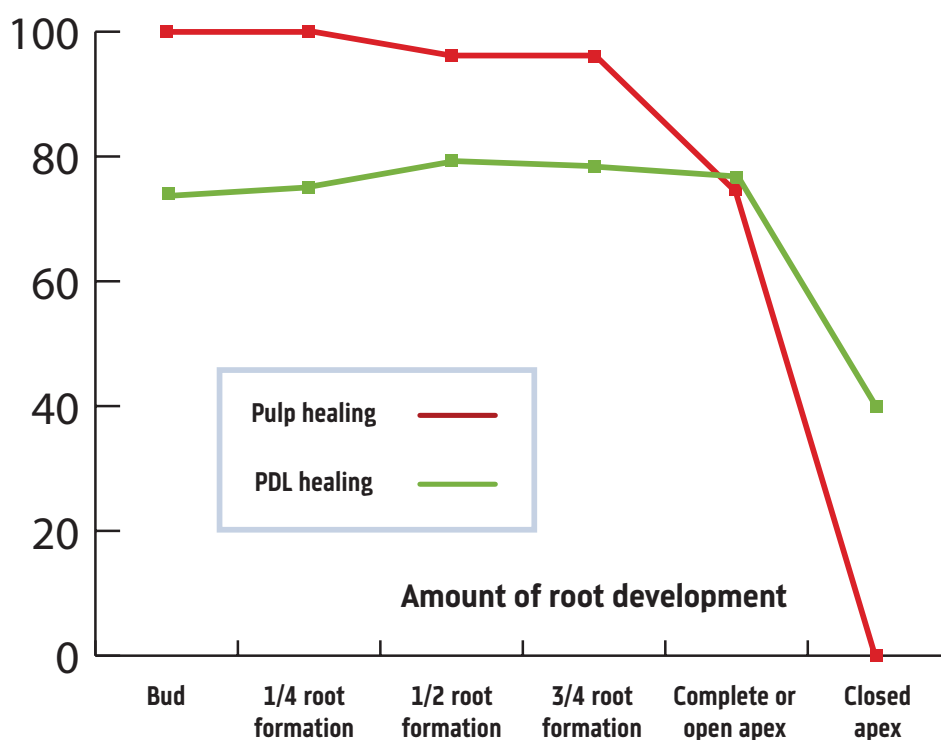
When the pulp can heal and continue root formation, the best outcome results.^{1,2,15} However, the tooth cannot be too immature; the ideal autotransplanted root is two-thirds to three-quarters formed,^{1,2,13,14,20} because the root can be placed in the new socket without excessive trauma and PDL cells are present, as well as an open apex into the pulp space: every critical component for success exists at this stage.^{1,2,6} In other words, the size of the apical foramen matters: a 2–3mm apical opening is best.^{5,14} Graph C illustrates the importance of the root development stage related to both pulp and PDL healing. Graph C also shows that while pulp healing is mostly independent of PDL healing, both are greatly dependent upon the stage of root development.^{1,2,18,20} One-half to three-quarters root formation results in the most success for both PDL and pulpal healing.^{1,2,5,13,14,18,20} Donor teeth with less than 50 percent root development have less PDL healing.^{6,20}

Conversely, similar to an avulsion scenario, if the apex of the donor tooth is closed, with an apical opening of less than 1mm, the pulp cannot heal.^{1,2,14}

Endodontic treatment is always necessary within 2 weeks of the AT, and has been shown to significantly reduce the incidence of IRR but cannot entirely prevent it.^{1,2,11,12,14,15,22,23} Likewise, graph C also reflects that when the root is completely closed (or open), less pulpal and PDL healing results.^{1,2} AT should be done when pulp (and PDL) healing can be expected to be the best and in an optimal environment for success.^{1-7,18-20} To summarize, a 1.5mm opening is the smallest suggested apical opening to attempt a AT without endodontic treatment being planned within 2 weeks. Yet, even with ideal three-quarters root formation, IRR, RRR or pulp necrosis can still result.²⁰

In the two cases presented, the first donor tooth was ideal, having three-quarters root formation with HERS visible⁵ and an open apex much greater than 1.5mm.^{2,14,15} In the second AT case, the donor tooth had greater than three-quarters root formation and a smaller apical foramen; however, even in the second AT case, the presence of HERS and an apical opening that was greater than 1.5mm still led to success.^{1,2,5,14}

Graph C
Healing related to root development



3. Alveolar bone health

A periapical radiolucency (PAL) does not contraindicate an AT procedure; when there is no PA radiolucency and healthy bone exists, a one-stage (or immediate) AT is possible,^{1,2} but existing PA inflammation/PAL should not preclude an AT procedure. Extraction of the affected tooth (with a PAL) should be planned approximately 2 weeks before the AT, in a two-stage procedure.^{1,2} A patient with moderate-to-severe horizontal bone loss and active periodontal disease will have less chance for success with an AT than a patient without periodontal disease or bone loss. Good buccal and lingual/palatal cortical walls are essential for both the stability of the AT as well as for healing. The lack of a sound alveolar wall/s reduces the success.^{1,2}

4. Donor-recipient size match

AT of a premolar donor to a molar recipient site would not necessarily be unsuccessful, but it may be less predictable. Success is always possible and is multifactorial. A more complicated donor (with multiple or curved roots) may also result in less success.^{1,2,23} A preoperative CBCT scan is highly encouraged for accurate comparison of dimensions and measurements.²² Similarly, it has been found that a larger recipient than donor (vs. a smaller recipient to larger donor) is more successful. Apparently, when the PDL heals from the donor site [outward], a better predictable outcome occurs rather than expecting bony healing from the recipient site (coming from bone marrow), which may result in IRR or RRR.¹¹

Additional contributing factors

As occlusion affects both the recipient and donor PDL cells, the autotransplanted tooth should be relieved out of static and excursive contacts so that no occlusal forces will interfere with healing. No periodontal probing or percussion tests should be performed until the newly established PDL is stable at 8–10 weeks post-AT.^{1,2,11,15,20}

For donor teeth with fully developed apices, orthograde endodontic treatment is recommended before AT.^{1,2,12} to avoid any adverse sequelae such as resorption or pulp necrosis.^{1,2,15,20,23} Without endodontic treatment, root resorption increases with a closed apex AT.¹⁵ If endodontic treatment cannot be initiated before AT, it should be initiated within 14 days^{1-3,12,13} of the AT procedure or when the transplanted tooth is able to withstand isolation with a rubber dam clamp.^{1,2,12} The tooth should be periodontally stable and secure, so no

PDL injury is caused during the endodontic procedure. Root resorption can occur when root development and the stage of eruption is less than ideal, or when orthodontic forces have been introduced.¹⁵ Root resorption is an unpredictable concern for each AT tooth since PDL/pulpal health can never be predicted._

For all other donor teeth without closed root apices—ideally more than 1–2mm—observation is recommended after transplantation to allow continued root and apical development. As the pulp heals, revascularization occurs. In time, PCO will become radiographically evident, and is considered a sign of a healthy and healing pulp.^{12,13,20} Once PCO is evident, cold tests will likely be negative; electric pulp testing is recommended to evaluate pulp vitality. However, if EPT is negative and PCO is evident, follow up closely and be suspect, because the pulp might be or become necrotic.²⁰ If signs and symptoms of pulpitis or pulp necrosis develop, endodontic treatment should be undertaken immediately.^{1,2,13,15,20,23} Note that EPT can be (falsely) negative in teeth with open apices¹², primarily when root formation is two-thirds to three-quarters complete, such as the teeth involved in these cases.¹² But, when both EPT and PCO are negative and at least 3 months has passed without further root development, then pulp necrosis has likely occurred (similar to occurrence in the more severe traumatic dental injuries).^{14,20}

Several long-term studies have examined AT. In 2002, Tsukiboshi reported about 250 ATs over 15 years, with an average follow-up period of 6 years; most were fully developed donor teeth.² Overall, he reported a 90 percent survival rate and an 82 percent success rate. AT into extracted sockets had a survival rate of 100 percent and a success rate of 95 percent, while AT survival into non-extraction sockets was 75 percent with a success rate of 60 percent. In 1990, Andreasen reported about 370 teeth with a 13-year follow-up showing 95–98 percent success.^{6,12,14,15} Lundberg in 1996 reported a 5-year follow-up of 275 teeth with 84–94 percent success.²¹

Few studies have predictably related orthodontic movement to the success of ATs.^{13,24–27} While it is highly encouraged to postpone orthodontic forces for at least 3 months after AT,^{13,22,24–27} the relationship between orthodontic forces and inflammatory resorption of the autotransplanted tooth needs to be studied further. It seems evident that orthodontic forces increase the propensity toward development of resorptions¹⁵ (IRR and SRR). When endodontic treatment is done as recommended, however, the likelihood of resorption

Table 3

Summary of AT clinical procedure ^{1,2,5,6,12,14-17,19,21,22}

- Examination, diagnosis, discuss adherence to follow-up visits, evaluate patient compliance.
- Treatment planning: oral hygiene instructions, timing of recipient socket status, orthograde endodontic therapy and/or orthodontic treatment (if needed) are all to be considered when planning.
- Surgical procedure setup: patient preparation; measurements (CBCT preferred over PAN); anesthesia; disinfection; preparation of recipient site/socket (one- or two-stage); extraction and preservation of donor tooth in tooth storage media: Hank's Balanced Salt Solution^{1,2,7-10} or similar; try-in and placement of donor tooth into recipient site; stabilize tooth¹² (with a resin-monofilament fishing line-splint/wire, if needed, for less than 6 weeks²); suture with gingival cuff, hugging tooth/CEJ as closely as possible^{1,2} to prevent bacterial wicking down into gingival sulcus; occlusal adjustments, if needed; and postoperative instructions.
- Suture removal recommended within 4–5 days² and no longer than 7 days,¹² and continued follow-up per Tables 1 and 2.

occurring greatly decreases. It is still unclear when to introduce orthodontic forces after trauma and/or AT, but literature suggests it's best to avoid orthodontic forces completely for a minimum of 6 months.^{13,24-27}

In the many existing publications, none has employed bite stents. When comparing the success of any endodontic procedure, particularly with a preoperative PAL, fabricating a bite stent on the tooth in question is encouraged. This is done by expressing bite registration material such as a VPS (vinyl polysiloxane: Regisil) on the top and bottom of the bite block used for PAs. The patient bites into this material while it hardens. Once set, the film is exposed with a film-holding device to duplicate the angle of the X-ray head at each subsequent visit. This way, the sensor, bite and teeth can always be in the same position so that radiographs can be exposed nearly identically each subsequent visit, and can therefore be compared nearly equally. Without bite stents, comparison can be difficult and unreliable. In future studies regarding AT, employment of bite stents

during follow-up visits to measure bony healing and success is highly encouraged.

Conclusions

Autotransplantation is a valuable treatment option that can continue bone development, especially for young, growing patients. It can be advantageous financially as well, preventing the need for restorative and prosthetic treatment. Practitioners should be made more aware of this excellent treatment alternative, and clinicians should collaborate to bring more of these procedures into mainstream practice. With proper planning and foresight, autotransplantation can be a highly successful solution rather than a removable partial denture or fixed bridge for unrestorable or missing teeth, as well as for teeth that have experienced a traumatic injury and cannot be saved.

Credits

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1. **Which factor is related to the success of autotransplantation?**
 - A. Stage of root development.
 - B. Infection of the pulp canal space.
 - C. PDL health.
 - D. All of the above.
2. **Autotransplantation is a novel procedure that only recently has become popular.**
 - A. True.
 - B. False.
3. **At how many weeks should a clinician safely assume that the PDL mostly "healed" after an AT procedure?**
 - A. 1 week.
 - B. 3 weeks.
 - C. 8 weeks.
 - D. 12 weeks.
4. **Within how many weeks after an AT should a root canal be commenced when the AT has a fully formed apex?**
 - A. 1 week.
 - B. 2 weeks.
 - C. 8 weeks.
 - D. 12 weeks.
5. **Root resorption is most related to which of the following factors:**
 - A. Orthodontic movement.
 - B. Root development of the AT tooth.
 - C. Stage of eruption of the AT tooth.
 - D. All of the above.
6. **If the cold test is negative on the AT tooth, what is the next step the clinician should take?**
 - A. Assume that the pulp has become necrotic, and do the root canal.
 - B. Continue PVTs with electric pulp testing.
 - C. Continue to monitor and follow-up/observe.
 - D. Take a radiograph at the next visit.
7. **How long should a clinician wait to safely apply orthodontic forces on an AT tooth so as to avoid most adverse sequelae?**
 - A. 1 month.
 - B. 2 months.
 - C. 6 months.
 - D. 1 year.
8. **Antibiotics should be given only after the autotransplantation procedure.**
 - A. True.
 - B. False.
9. **It is best to rotate the tooth ___ degrees to maximize the M-D width of the AT tooth in its new location.**
 - A. 30.
 - B. 45.
 - C. 90.
 - D. 180.
10. **Predictable success of an AT procedure is best when the root apex is more than ___ wide in the apical foramen?**
 - A. 0.1mm.
 - B. 0.5mm.
 - C. 1.5mm.
 - D. 3.0mm.

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