When contemplating replantation and autotransplantation, the main focus for orthodontists is likely to be the advantages of autotransplantation, which has become an attractive treatment for replacing missing maxillary incisors. The focus of this article will be on a comparison between teeth replanted as autotransplants and those replanted after traumatic avulsion.

Dentists tend to think that most replanted avulsed teeth have a poor long-term prognosis and create problematic restorative situations. These concerns are focused on the potential for a replanted tooth to become ankylosed. Replantation of an avulsed tooth, however, does not necessarily guarantee that the tooth will become ankylosed and give rise to a deficient alveolar ridge, nor does it preclude autotransplantation as a subsequent consideration.

When considering replantation vs autotransplantation of an avulsed tooth, the difference in published success rates appears to favor autotransplantation. Although success rates are important, they are not the sole consideration in the management of a missing anterior tooth. Reported success rates for autotransplanted teeth range from 21% to 100%. For autotransplanted premolars to the anterior region of the mouth, the success rate claims are 79% to 93%. The success rates for replanted teeth after traumatic avulsion are 9% to 50%. However, Andreasen and Andreasen and others have claimed success rates between 71% and 82% when avulsed teeth are replanted under more favorable conditions. The disparate success rates arise from the clinician’s ability to control important variables during autotransplantation vs no control of most circumstances after a traumatic avulsion. A surgeon has control of important variables such as extra-alveolar dry time and physiologic wetting solutions during autotransplantation, whereas a clinician commonly has no control over what happens to a tooth immediately after it is avulsed.

In ideal clinical management, primarily 2 tissues, the periodontal ligament and the pulp, are injured during autotransplantation. In contrast, the periodontal ligament, pulp, cementum, alveolar bone, and gingiva might all be damaged in the trauma involving an avulsed or a displaced tooth. The more structures that are injured, the more complicated and unpredictable the survival and return to function of these tissues becomes. From an endodontic perspective, however, most pulpal problems can be resolved with endodontic treatment in either autotransplantation or replantation of an avulsed tooth.

POTENTIAL FOR ANKYLOSIS

The main concern in the treatment of a growing child is the potential for ankylosis of a replanted tooth. Ankylosis is fusion of the alveolar bone and the root surface. It produces 2 clinical consequences—replacement resorption and arrested ridge development. Replacement resorption is the progressive resorption of the root of the tooth and its replacement by bone. If it occurs, this characteristic can be used to a clinical advantage. Arrested development of the alveolar ridge associated with an ankylosed tooth can result in a progressive vertical ridge defect as a child grows. Adequate augmentation of these large defects remains a difficult clinical challenge. These extensive ridge deformities have raised so many concerns that one consideration is that teeth with an extra-alveolar time greater than 5 minutes should not be replanted. But that approach comes...
with its own set of problems. These include long-term temporization for a growing child, progressive ridge resorption in the avulsion site that requires additional separate grafting procedures, and the need for additional orthodontic treatment.

Although there has been extensive research related to replantation of avulsed teeth, ankylosis remains the predominant clinical problem. Inquiries into the factors that affect replantation success have been published since the mid-1800s. Over time, research suggests that the most important variable in preventing ankylosis and replacement resorption is a viable periodontal ligament on the root of the tooth at the replantation. Periodontal ligament viability is primarily associated with how long a tooth is out of the socket and the effect of the physiologic storage medium during the extraoral time. Immediate replantation (less than 5 minutes) is best for the preservation of a viable periodontal ligament. In fact, viability of the periodontal ligament remains high with an extra-alveolar dry time up to 15 minutes.

Limiting the time the periodontal ligament is dry while a tooth is out of the socket might also decrease the incidence of ankylosis. Hank’s balanced salt solution (SAVE-A-TOOTH; Phoenix-Lazerus, Inc, Pottstown, Pa) is the preferred medium to preserve periodontal ligament viability. As a practical matter, however, cold milk and saliva are more likely to be immediately at hand. Cold milk can keep the periodontal ligament cells viable for about 6 hours, and saliva for 30 minutes. Although laboratory research has established time parameters for the efficacy of storage media in maintaining the viability of the periodontal ligament, correlation of such data with prevention of ankylosis is not yet available.

**ADVANTAGES OF REPLANTATION**

Replantation of an avulsed tooth is a basic starting point even when the ideal conditions to prevent ankylosis cannot be met. With replantation, long-term treatment decisions need not be made while managing an emergency. To construct a complex treatment plan at the time of the tooth avulsion is an unreasonable expectation. Replanting an avulsed tooth will allow interdisciplinary consultations and a definitive treatment plan to ensue in a deliberate fashion. In addition, a replanted tooth can serve as an interim replacement. It can also act as a scaffold to prevent rapid loss of alveolar bone during remodeling of the socket. An alternative to replantation is to place a socket graft to preserve the alveolar ridge. This seems like a simple solution. Nevertheless, most accidents occur between the ages of 8 and 12 years. A socket graft must preserve the alveolar ridge until the child has stopped growing, often for a period of 5 to 10 years. In a series of patients followed for 3 to 7 years after traumatic tooth loss in the anterior maxilla, socket grafting failed in 82.4% of the sites to provide sufficient bone to support the placement of a dental implant without an additional bone graft.

If a replanted tooth becomes ankylosed, it does not preclude subsequent autotransplantation. Ankylosis can be clinically diagnosed as early as 2 months after replantation; most cases are found within 6 months to 1 year. If a tooth does become ankylosed and

---

**Fig.** Replantation of an avulsed central incisor followed by implant replacement. A, The maxillary right central incisor was avulsed and replanted at age 10. At age 13, the incisal edge was lengthened with composite. Ankylosis of the right central incisor caused a gingival margin discrepancy with the left central incisor. B, At age 15, the incisal length of the ankylosed and submerged right central incisor was increased with composite to help facilitate orthodontic treatment. After orthodontic treatment, the right central incisor was extracted, and a bone graft was placed in the alveolar ridge. C, At age 19, the patient had completed her facial growth, and an implant and a crown were placed in the grafted alveolar ridge to replace the missing right central incisor (courtesy of Drs Ron Kuritani, Daniel Cook, David Crouch, David Mathews, and Beth O’Connor).
the child is a candidate for autotransplantation, the tooth can still be removed without missing the optimal time for transplantation success.

Finally and most importantly, when a decision is made to replant a tooth, it is crucial that the primary dentist, specialists, and parents all assume responsibility for monitoring the child’s dentition for signs of replacement resorption. Together, each will have a role in ensuring that any upcoming decision regarding autotransplantation or decoronation is made and performed at the appropriate time (Fig).

DECORONATION

Decoronation of an ankylosed tooth is 1 solution that has been proposed to prevent or mitigate a large ridge defect in a growing child. First described in 1984, decoronation involves removal of the crown and endodontic filling material from the root of an ankylosed tooth, allowing the tissue to heal over the retained root. Results have shown that new bone can develop coronally to the root remnant. In addition, the retained root maintains the labial contours of the ridge directly over the root as the root is resorbed and replaced by bone. Yet, in some case reports, the clinical outcomes of decoronation appear to be inconsistent or unsatisfactory. These reports have raised the question of the efficacy of the decoronation procedure. In some case reports, decoronation was carried out too late to take advantage of adolescent growth. If decoronation were performed late in the growth spurt, 2 factors would combine to produce a deficient ridge in the decoronation site.

First, most of the vertical growth of the alveolar ridge and the eruption of the adjacent teeth are missed. Second, the presence of the crown of the ankylosed tooth prevents vertical and horizontal bone growth coronally to the alabial aspect of the retained crown. Thus, decoronating this late in adolescent growth is little better than an extraction and does not eliminate the need for additional separate grafting procedures.

Is it possible to alter the decoronation procedure to achieve an optimal outcome? The mixed results after decoronation can be explained, in part, by when the procedure is performed and the extended facial growth after ankylosis. Decoronating an ankylosed tooth at or near the start of adolescent rapid growth should facilitate associated alveolar bone growth as the adjacent teeth erupt. This timing should lead to the greatest deposition of alveolar bone coronally to the retained root. Clinical observations suggest that the labio-palatal width of the ridge has a trapezoidal shape coronally to a decoronated root. The base of the trapezoid is the root undergoing replacement resorption. In instances of considerable vertical midfacial growth, the distance increases from the retained root to the coronal portion of the ridge. This distance can result in the level of the resorbing root being positioned too apically for it to add bone at the ideal level adjacent to the labial aspect of the implant head. Even so, the resorbing root would increase the volume of labial bone in the apical region of the implant. But, as the height of the developing ridge continues to increase, the coronal aspect of the ridge might become too narrow to support an implant without a graft. In short, proper timing of decoronation can increase the likelihood of an adequate implant site or a ridge width that would allow for a single surgery that combines grafting and implant placement. But, in instances of prolonged vertical midfacial growth, even with the additional bone volume from decoronation, the coronal ridge might still require separate additional grafting in spite of seemingly proper timing and appropriate technical management of the decoronation.

TIMING THE APPROPRIATE TREATMENT

How does a clinician judge the possible extent of a ridge defect and know when to intervene? By beginning with median growth data for the start of adolescent rapid growth and refining that information by observation and key questions, both the time to decoronate and the extent of the defect can be estimated. A simple observation by the parents is to record the skeletal height of the child every 3 months beginning 6 months to 1 year before the median age for rapid growth. A distinct change in height indicates that rapid growth has begun. In practice, after determining that a child is in the initial stages of a growth spurt, an ankylosed tooth should be decoronated when it is 2 to 2.5 mm in infraocclusion. The tooth will have served as an interim temporary and space maintainer up to that point, and decoronating it at this level of infraocclusion can capture most of the adolescent rapid growth. After the completion of growth, ridge height might be imperfect but adequate, since implants are generally placed about 3 mm apically to an ideal gingival margin. Even if decoronation does not always obtain an ideal ridge, any mitigation of a defect would seem welcome. Not replanting a tooth after avulsion produces a deficient ridge; socket grafting as an alternative to replantation is not a long-term solution; and, relative to those choices, decoronation of an ankylosed replanted tooth can moderate a ridge defect enough that the extent and number of grafts are reduced.
Up to this point, the discussion has been limited to children and adolescents. In adults, the clinical management and prognosis differs somewhat for a replanted avulsed tooth. Immediate replantation has the best prognosis in both groups. An alveolar ridge defect does not develop in an adult, even if the tooth becomes ankylosed since facial growth has ceased. Furthermore, Andreasen and Andreasen found that 70% of ankylosed teeth with mature roots survive for 10 years. In contrast, 50% of ankylosed teeth with immature roots survive 10 years because the rate of resorption is much more rapid in children.

**LIMITATIONS OF AUTOTRANSPLANTATION**

Replantation of an avulsed tooth comes with predictable issues that have workable solutions. It is a reasonable clinical practice to replant an avulsed anterior tooth. Autotransplantation also has a place in replacing missing incisors. But, as with all treatment choices, it has limitations. Optimal results occur within a relatively narrow age range. Specifically, treatment outcomes are best when the root of the donor tooth is two thirds to three quarters formed. That limits the best candidates for treatment to children 9 to 12 years of age. When the root length does not fall within this range, healing of the periodontal ligament can decrease by up to 34% when the foramen of a donor tooth is not wide open. Also, complications in obtaining an optimal root length can increase by up to 25% when the donor tooth’s root is less than half formed. In patients aged 40 years and younger, Tsukiboshi found that success falls to 75% when a tooth is transplanted into an artificially formed socket rather than transplanted into an immediate extraction site. Autotransplanted teeth also present anatomic concerns. In a bilateral comparison of autotransplanted teeth, about 60% were dissimilar in appearance with regard to an asymmetric gingival width or a color mismatch. About 25% of the patients were not satisfied with those esthetic outcomes.

As well as these specifics for an optimal outcome, the autotransplantation procedure can make a nonsurgical approach technically undesirable. External resorption near the cementoenamel junction will require surgical repair of the defect with a restoration in the esthetic zone. In addition to these possible complications, premolars autotransplanted to the maxillary anterior region are often positioned apically to the incisal level of adjacent teeth. If the tooth ankyloses at that level, it would be in infraposition. There would be a ready-made alveolar ridge defect, and decoronation or grafting of the site would be necessary.

**CONCLUSIONS**

Based on the previous discussion, the following conclusions can be made.

1. It is a reasonable clinical practice to replant an avulsed anterior tooth.
2. Socket grafting in children is not an effective alternative to replantation of an avulsed tooth.
3. The timing for decoronation of an ankylosed tooth is critical to its outcome.
4. Optimal results for autotransplantation are achieved within a narrow age range.

I thank Dr. Gerald W. Harrington, Professor Emeritus, Department of Endodontics, School of Dentistry, University of Washington, for his expert help in preparing this paper.

**REFERENCES**