Autogenic tooth transplantation

The “state of the art”


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With proper case selection and technique, autogenic tooth transplantation can be a viable treatment modality. The authors present a number of transplant cases and suggest the procedure be considered as an adjunct in orthodontic treatment planning. A comprehensive review of the literature, combined with the authors’ opinions and clinical demonstrations, has culminated in a discussion of indications and contraindications, special considerations, optimal timing, technique, and prognosis. It is thought that appropriate utilization can simplify or eliminate prosthetic requirements, reduce the complexity of many orthodontic treatment plans, and convert into routine certain cases heretofore thought to be inoperable.

The primary objective of comprehensive dental treatment planning is conservation of tooth tissue. The absence of teeth, either congenital or due to caries or trauma, presents a challenge to the concept of conservative tissue treatment. Orthodontic space closure and prosthetic replacement are two possible approaches to solving this problem, but these can result in compromises of esthetics, symmetry, occlusal function, or periodontal stability. This article is intended to be an exposé on the “state of the art” of yet another approach, namely, autogenic tooth transplantation. This procedure has improved to the point where it might be considered as part of our everyday armamentarium. Its use can give the concept of space management a much broader horizon. A careful review of the literature bears out many differences in technique, as well as in success rates; special effort has been taken to summarize these and provide a realistic, modern methodology.

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Transplantation is the transfer of tissue or an organ from one site to another. This discussion confines itself largely to autogenic or autoplastic transplantation, where the donor and the recipient are the same individual. Allogenic transplants, from one individual to another within the same species, too often cause an immunologic reaction resulting in failure and are not considered to be realistic alternatives at present.

**Clinical considerations**

Many of the indications and contraindications are quite obvious, but attention must be paid to every aspect of the procedure to enhance an optimal result.

*Source of transplants.* Any tooth within the patient's dentition might be a candidate for transplantation. Third molars have been most frequently used, for a number of reasons. These teeth, which otherwise are often extracted, have served well as replacements for cariously destroyed first molars. Moreover, their root development which continues into the late teens and twenties makes these teeth suitable for use into adulthood. Premolars have also been readily available as transplants, especially since their extraction is often indicated in the orthodontic treatment plan. Furthermore, their anatomy is frequently better suited for more mesial replacements (Fig. 1). Lower incisors have been used to
replace upper lateral incisors,⁷ and impacted canines have been surgically repositioned in extreme cases.⁸,⁹

Size of transplant. Seldom does one have much choice in the matter of donor selection. Nevertheless, consideration should be given to the size of the recipient area—whether the transplant exceeds in any dimension the space available in the recipient region.³ Mesiodistal assessments are easily performed, but it is often difficult to determine the labiolingual width of a donor root base and whether it can be made to fit well within the alveolar walls. Occlusal radiographs are recommended for such assessments (Fig. 2). Depending upon the space available, the more limited size of the premolar may make this tooth a more favorable candidate than a third molar. On the other hand, the last tooth in the arch may offer better access for removal, and it is essential that the root not be damaged in any way during its relocation.

Timing of transplant. Since a primary objective is to obtain maximum root length of the transplant, timing becomes critical for a number of reasons. Slagsvold and Bjercke⁶ have shown that transplantation performed near the time of completion of crown forma-
Fig. 1F. Six months postoperatively, showing healthy lamina dura.

Fig. 2A. In this unfortunate predicament where a practitioner had initiated serial extraction without confirming the presence of all teeth radiographically, the compromise decision was made to place an upper third molar into a lower premolar site.

...tion can adversely affect enamel calcification. On the other hand, the prognosis for successful transplantation is diminished as the root apex nears closure. It should be borne in mind that revascularization must take place. While Agnew and Fong\textsuperscript{10} have documented a re-establishment of blood supply within a closed apex, this is more easily accomplished at an earlier stage.

For the tooth in the bud stage of development, surgical manipulation is a traumatic episode and further development from that point forward may not be normal. Postoperative root formation is often stunted or may take on morphologic aberrations (Fig. 3). Moreover, studies have shown a significant reduction in final root length when compared with the contralateral side, but there is less than a 5 percent probability that the reduction will exceed 2.3 mm.\textsuperscript{7} While postoperative resorption is rarely reported, it is nevertheless thought that the effective reduction in root length is minimized by allowing adequate development prior to transplantation.

Conversely, the longer the root at the time of surgical intervention, the greater is the depth required at the recipient site. Encroachment upon the maxillary sinus or the mandibular canal must be a consideration. As it is preferable to relocate the tooth out of occlusion and subsequently allow it to erupt to a position of antagonism, additional depth...
Fig. 2B and C. As the alveolus was not of adequate width labiolingually, the root tip is palpable and there is not an ideal contour of alveolar support.

Fig. 2D and E. In spite of the situation shown in Fig. 2B and C, there has been an improvement in the periodontal status of the region subsequent to the transplantation. It is thought that the transplant has a better prognosis than the retained deciduous molar might have had.

of socket preparation may be required. Hale\textsuperscript{11} has stated that “the length of the root of a developing dental transplant depends on the degree of preparation of apical depth of the placement at the time of surgery.” Like many authors,\textsuperscript{2, 12} Hale believed that the most favorable time for transplanting was at 3 to 5 mm. of root formation. Apfel\textsuperscript{2} stressed the need for delaying transplantation until after furcation formation. Numerous researchers
Fig. 3A and B. Male patient of orthodontic age whose third molar was transplanted into the site of an impacted second molar in August, 1964. 3B, September, 1964, one month postoperatively.

Fig. 3C and D. February, 1965, and July, 1965. After what appeared to be a period of arrested growth, some apical displacement of bone is now taking place.

Fig. 3E to H. E, January, 1966. F, October, 1966. G, October, 1966, 2-year postorthodontic follow-up. H, September, 1975, following extraction of first permanent molar, apparently because of the gradual breakdown of his restorations, the patient presented to the McGill University undergraduate dental clinic.
have contended that results will be maximized if the operations are performed some-
time between one third and three fourths of completion of root formation, but
Slagsvold and Bjercke have shown successful premolar transplants at all stages of root
formation. The genetic potential of a properly handled transplant can sometimes provide a
response which exceeds the anticipated. While we would generally agree with the theory
advanced by Hale, especially from the standpoint of treatment plan timing and objectives,
the developing tooth has the potential for apical bony displacement and root elongation
(Fig. 3).

Timing can also have a bearing on the recipient site. Proper alveolar architecture is
essential for housing the transplant. If the recipient site is edentulous, the alveolar contour
will often be underdeveloped (sometimes nonexistent) and the procedure is not advisable.
The maintenance of deciduous teeth in these areas becomes very important. If this re-
placement is planned, these teeth should be kept free from pathologic processes, and it is
desirable to delay extraction until the time of transplantation as the extraction site provides
the basis of a crypt for placement.

Recipient site. Our primary concern in selection of a recipient site is one of periodontal
integrity. In this regard, a suitable site must have sufficient alveolar support in all
dimensions; it should be covered with adequate attached, keratinized tissue to allow
proper coverage or approximation to the transplant, and it should be free of chronic
inflammation.

As we shall discuss later, there should be minimal manipulation of the transplant.
Bearing this in mind, we suggest that mesiodistal space deficiencies be eliminated prior to
the surgical procedure, either by orthodontic means or by slicing of adjacent teeth. Also,
there should be adequate labiolingual width on the ridge to accommodate alveolar plates
on both surfaces. The proper depth of preparation can be tested by trial insertion of a
“dummy” tooth which can be replicated in advance to precise dimensions by long-cone
and occlusal radiography (Fig. 4). With fit and depth of cavity preparation being assured
in this way, the transplant can be moved without delay from the donor site directly to the
recipient field. In the event that the transplant is too small, Costich recommends the
filling in of “dead space” with bony fragments. While this technique is not universally
advocated and should not be necessary, these fragments could be prepared in advance if
their use is anticipated. Nordenram and Bergman disclosed better results in the maxilla
than in the mandible, but they are the only authors to find a preferred region for transplan-
Fig. 4. Dummy tooth fabricated in acrylic to match as closely as possible the dimensions of the transplant. Further, it has been our experience that the maxillary sinus tends to limit the potential size of the socket to be created and thus the prognosis in this arch.

The surgical technique

The basic surgical technique that is advocated is not new; the technique described by Hale\(^\text{11}\) in 1956, for example, describes nicely the mechanics of a very adequate approach. Nevertheless, we believe that strong emphasis should be placed on certain basic philosophic concepts: proper selection and preparation of patients, gentle handling of soft-tissue structures, and minimal handling of the transplant. Great care should be taken not to denude or even touch, where possible, any of the root sheath or exposed pulpal tissue. If fundamental surgical principles are followed, a well-planned transplant should have an excellent prognosis.

The recipient site should be free of all pathologic processes. If a tooth in this region is abscessing or contributing to periodontal problems it should be removed, and time given for the area, especially the soft tissues, to become healthy. The use of antibiotics is necessary only when local problems have not been satisfactorily eradicated prior to the transplantation procedure, or where specifically indicated for a particular systemic problem.

Local anesthesia is sufficient and, in fact, preferable to other alternatives. As success is so dependent upon the patient's cooperation, it helps if the patient understands and takes part in the procedure as if it were a cooperative affair. The procedure should present an opportunity to demonstrate the care and concern that the practitioners are investing in the treatment and provide an opportunity to develop a better understanding of the complexities involved. With this understanding the patient is in a better position to partake in the preservation of the transplant.

A full-thickness mucoperiosteal flap should be employed, allowing adequate exposure for atraumatic preparation of the recipient site. Special care should be taken to ensure a very gentle handling of the soft tissue. If a deciduous or condemned tooth is being removed for preparation of the crypt, attention should be given to minimizing the destruction or removal of crestal bone. The socket is prepared with bone burs and rongeurs of the surgeon's choice. Once the socket is judged to be of adequate depth and circumference, a trial insertion of the presterilized dummy tooth can be made. Ideally, the preparation of the recipient site will allow insertion deep enough that the cusp tips will be at or apical to the alveolar crest height. This allows eruption and hence root formation postoperatively.
Fig. 5A. Female patient in mixed dentition, with large edentulous area subsequent to a snowmobile accident.

Fig. 5B and C. Placement of the transplant in rotated position accommodates limited labiolingual alveolar dimension and, at the same time, consumes maximal arch length.

With the host site prepared, the transplant can be removed. Again, adequate flaps allow exposure and a minimum of trauma. With gentle manipulation of surgical instruments (forceps, elevators, etc.), the dental follicle is removed from around the crown; the tooth is removed and transferred immediately into the previously prepared crypt. Studies have shown an inverse relation between rate of success and the amount of time that elapses between removal and reimplantation.\(^1\) We prefer this to be a nonstop procedure, allowing only for proper orientation within the socket and its preparation. It is preferable that the tooth be manipulated only by its crown.\(^9\) In the event that buccolingual width does not allow proper placement (especially in the case of a maxillary premolar), it can be inserted in a rotated position. This will allow preservation of alveolar crest and the tooth can later be repositioned orthodontically as desired (Fig. 5).

The mucoperiosteal flap is now repositioned and 3 0 black silk sutures are placed over the crown to hold the tissues together and the tooth in its crypt. If anatomic structures (maxillary sinus or mandibular canal) do not allow adequate apical positioning, histoacryl can be used to tack the gingival margin to the coronal portion.

The patient is given oral hygiene instructions and cautioned against eating on the operated side. After a week or 10 days the ligatures can be removed, and direct bonded stabilization can be employed to protect the tooth while the patient resumes function on
that side of the arch. As this can be kept on the occlusal surface or at least away from the gingival margin, the placement can be very conservative and hence hygienic (Fig. 6).

Retrograde endodontic treatments have been performed simultaneous to transplantation with varying degrees of success—none of them very good.\(^5\),\(^6\) Not only would such treatment introduce a foreign substance into the site, possibly inducing an inflammatory reaction, but it greatly increases the length of the procedure and the time the transplant remains out of the mouth. Further, such manipulation will assuredly traumatize the root surface. As Nordenram and Bergman\(^5\) demonstrate, it would be more judicious to perform the root canal treatment after the periodontal ligament has readapted \textit{if such treatment proves necessary}. For similar reasons, any of the methods advocated for storage are thought to be unwarranted.\(^17\),\(^18\)

\textbf{Stabilization}

We believe that the subjects of ligation and immobilization deserve special attention. It is important that mobility between healing parts be minimized in order to accelerate the cellular proliferation and reduce osteoclastic activity. Similarly, the transplant should be free from occlusal forces during this healing period.\(^5\),\(^19\),\(^20\),\(^21\)

We are firmly committed to the philosophy that the use of circumdental ligation at the level of the cementoenamel junction is contraindicated. While many authors have advocated its use,\(^11\),\(^20\),\(^22\) Andreason and associates\(^1\) found deepening of the periodontal sulcus and pocket formation to have a direct correlation with those cases which were splinted for a longer period of time. Moss\(^9\) found that in all cases showing resorption following transplantation this pathologic process occurred at the point where the tooth has been surgically elevated with an instrument; he concluded that trauma on the root surface should be avoided. Cook,\(^20\) who routinely used ligation to secure his transplants, noted that the most common site of resorption was at the cementoenamel junction. Vanarsdall,\(^23\) in studying forty nonerupting teeth, found the most common sequelae to circumferential ligation to be external root resorption and ankylosis (Fig. 7).

Some of the unfortunate sequelae to circumdental ligation are as follows: The ultimate periodontal attachment and contour are seldom normal and, subsequently, external root resorption can be initiated at this site; this step would require further manipulation at a critical point in the procedure.

Our experience has taught us that the need for immobilization is determined by the site
Fig. 6A. Transplant held in position by 3-0 black silk sutures.

Fig. 6B. Direct-bonded “stabilization” can be used if indicated, preferably some days following the surgical procedure.

of the surgical procedure and the vertical placement of the transplant. With adequate depth of preparation at the recipient site, sutures and proper diet management may provide sufficient fixation. The recent improvements in direct-bonding materials have made it possible to provide a nontraumatic, hygienic method of protecting even the most cumber-some of transplants. Excessive periopacking or acrylic stabilization are not desirable, as they impede efforts in oral hygiene and give the patient the feeling that the tooth is protected, thus removing his responsibility. Finally, the emphasis at this point should be not on rigidity but on loose fixation. Complete rigidity during the initial healing may increase the chances of ankylosis or an otherwise nonphysiologic union.

**Histophysiologic response**

Basically, the physiologic response following autogenic tooth transplantation is a combination of normal healing and continued growth and development of the tooth germ with its capacity for differentiation. Adverse immunologic reaction should not be a factor, since the graft is autogenous in nature. Aside from the normal physiologic response, certain changes in the tissues often result.
Fig. 7A and B. A, Female patient, 14 years 6 months of age with an impacted lower left second premolar. B, Regardless of careful instructions to the surgeon for an alternate procedure, the patient was returned with circumdental ligation.

Fig. 7C and D. C, In spite of its early removal (before the tooth had penetrated the gingiva), the tooth developed external root resorption at the cervix. D, The lesion worsened as it continued its eruption until restoration was finally placed.

In vivo experimentation has been performed in animals to study the nature of physiologic change in the aftermath of transplantation. Histologic investigations have also been carried out by means of Ca and qualitative analysis of autoradiograms and microradiograms. In other studies, teeth scheduled for extraction in orthodontic patients have been transplanted and then subsequently extracted to permit histologic evaluation. The clinical and radiographic changes occurring in the animal studies have been in general agreement with those seen in human studies. These have all helped to confirm the "physiologic" incorporation of the graft into the new region.
Fig. 8A. Male patient, 12 years 9 months of age, in February, 1977, with agenesis of all maxillary premolars, both canines, and the left lateral incisor. He was also missing two lower premolars and an incisor.

Fig. 8B. Sixteen months later; lower space is being consolidated and the lower right third molar has been transplanted to the upper premolar region.

Microscopic changes

The histologic findings of a number of investigators are in close agreement, and a general summary of these results following a transplant seems warranted. By the second postoperative day the odontoblastic layer of the pulp chamber shows areas of detachment from the pulp wall, and an inflammatory infiltrate with associated hyperemia is present. There is a temporary period (3 to 5 days) of relative nutritional deprivation until revascularization occurs. During this period nutrition is probably supplied to the transplant by diffusion of fluid from surrounding tissues. By the fourth day the pulp shows localized areas of necrotic pulp tissue; however, the periodontal ligament has become highly vascularized and a gradual regeneration or replacement is under way. A proliferation of connective tissue continues and gradual reorganization results in a satisfactory union between
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Fig. 8C. March, 1979, 5 months after second transplant; space closure and protraction have been initiated in the upper arch. Orthodontic treatment will provide opposing teeth for the upper second molars after upper space consolidation.

Fig. 8D and E. September, 1979, root formation progressing nicely; what had been a high-risk prosthettic situation should have a good prognosis when treatment is finished.

bone and cementum. Loe has demonstrated that by the thirtieth day the periodontal ligament closely resembles the control.32

Using microradiograms Rockert and Ohman29 have found extensive areas of demineralization of the cementum layer in transplanted human teeth which were subsequently extracted for observation. Although great care had been taken to preserve the periodontal membrane and minimize the time the tooth was out of the mouth during transplantation (two factors known to have tremendous effect on the quality of result),21, 30, 32 this form of response was not avoided. While Frostell4 had reported subsequent filling of these areas of resorption by new cementum, Rockert and Ohman29 could not corroborate this finding. Birman and DeAranjo26 transplanted teeth into the subcutaneous tissue layers of rabbits and found that the integrity of the periodontal ligament was “essential” to any contiguity that would be established between the tooth and the surrounding connective tissue. In denuded areas the cementum would not form a healthy union. It is not felt that the degree of resorption suffered under careful technique is not critical to the success of transplanted teeth.

While areas of demineralized dentin have been found,29 the pulpal tissues tend to
appear normal in the middle and apical thirds of the root by the end of the third month. On the other hand, the coronal portion of the pulp, as well as most of the newly developed root mass, will generally be filled in with osteodentin or a mixture of connective tissue rich in collagen, resembling spongy bone. During this period, there is a transition from highly differentiated odontoblasts lining the walls of the pulp chamber into cells of the fibroblast type.

**Macroscopic changes**

Just as the neonatal line occurs as a result of birth trauma, some degree of developmental disturbance can occur at the time of transplantation. This often manifests as a thickening or distortion of root structure (Fig. 3). Slagsvold and Bjercke state that this perhaps is due to a distortion of the epithelial sheath at the time of surgery. Resumption of normal root formation usually occurs, but often there is some curtailment of maximal root development. Pronounced pocket formation and gingival inflammation are not generally seen. In many instances normal or slightly reduced vitalometer readings are registered on transplanted teeth. However, as Guralnick and Shulman have postulated, after a new blood supply has been established and the periodontal ligament restored, the tooth should be considered vital regardless of the status of nerve regeneration (Fig. 8).

**Prognosis**

Examination of the available literature regarding prognosis of autogenous dental transplants clearly demonstrates that the rate of success varies with the technique and with attention given to care. The excellent efforts of Slagsvold and Bjercke, with no failures in thirty-four transplants, are testimony that autogenic transplantation is a legitimate treatment modality. Although one tooth showed some postoperative resorption, one appeared to be ankylosed, and there was a generalized shortening of ultimate root length, all of their transplants have proved to be satisfactorily functioning dental units. And this, after all, is the ultimate test of success.

As the reorganization of nervous tissue subsequent to transplantation seldom provides a typical sensitivity response, it is not thought that a vitalometer reading should be an indication of success or failure. We would prefer that attention be given to the health of the supporting structures. One should expect to see normal color, form, and integrity of the gingival tissues. It should be possible to probe the gingival sulcus at normal depths, and alveolar bone should be palpable on the labial and lingual surfaces. A normal alveolar bone level should be demonstrable radiographically. There should be a favorable crown-to-root ratio and a potential for further root development. The root shape should not be grossly altered. The periodontal space should be of normal thickness and should completely circumscribe the tooth. While Hale found that apical thickening of the lamina dura may be a sign of impeded root development, it is expected that a normal lamina dura will form on the circumference of a successful transplant. Occlusal contacts should not be excessive, and the tooth should maintain a normal eruptive potential. The tooth should not be unusually mobile. Given these clinical signs, the transplant has a good prognosis and should perform like any other tooth in the arch.

**Summary**

Autogenic tooth transplantation is a treatment modality whose time has come. In properly selected cases the need for prostheses can be eliminated; orthodontic treatment
can usually be reduced, alleviating many of the anticipated side effects (deepened bites, flattened facial profiles, relapse, etc.); and maximal conservation of tooth tissue is brought to its fullest potential. In this article we have attempted to review, in depth, the available literature, discuss the principles of transplantation and response, and provide sufficient cases to demonstrate the value of this procedure to comprehensive treatment planning.

1. Cases must be carefully selected; we believe that the patient’s ability to comprehend and cooperate is critical.

2. Most authors agree that the procedure is best performed when the root length of the transplant is between one half and three fourths complete.

3. The recipient site must be healthy and of adequate size to receive the transplant; it is important that the recipient site be prepared before the transplant is made available.

4. Tremendous care must be exercised not to insult the root surface; wherever possible, the transplant should be handled only by its crown.

5. The length of time from removal to reinsertion should be minimal; ideally, this is a nonstop relocation. Desiccation of the periodontal ligament can cause resorption, ankylosis, and failure.

6. Root-filling procedures are contraindicated.

7. Careful surgical technique and management of soft tissues cannot be overemphasized.

8. Circumdental ligation with metallic sutures is contraindicated.

9. Soft-tissue reproximation and ligation with silk sutures, combined with great care on the part of the patient, constitute a preferred form of fixation during the first ten days.

10. Further stabilization can be employed through direct bonding, if necessary, for from 10 days to 6 weeks. After this time the tooth should be treated like any other tooth of similar developmental stage.

11. The chance of a favorable prognosis for a properly prepared autogenic dental transplant can approach 100 percent.

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