Esthetic Substitution and Autotransplantation of Teeth in the Maxillary Anterior Region

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In the context of congenitally absent or traumatically avulsed teeth in the maxillary anterior region of the dental arch of a preadolescent, the most efficient, enduring, timely, and cost-effective solution is one and the same: the use of natural dentition. In the previous 5 decades, extensive resources have been allocated to the study of autotransplantation procedures, which frequently reflect a high success rate. In addition, improvements in orthodontic positioning and restorations continue to enhance outcomes of dental substitutions. Various studies have reviewed treatment alternatives for individuals experiencing congenitally missing or traumatically lost maxillary anterior teeth; however, reports discussing *both* substitution and autotransplantation as viable treatment options in this region were not previously available. The methodology and necessary considerations pertaining to canine substitution for a maxillary lateral incisor, cuspid substitution for a premolar, lateral substitution for a maxillary central incisor, and autotransplantation of a mandibular premolar for a missing incisor are discussed in detail. (Semin Orthod 2013;19:3-12.)

Orthodontics blends biology, engineering, and art. Few situations require more harmony among these 3 disciplines than the replacement of a missing tooth in the maxillary anterior region, commonly called the esthetic zone. Whether choosing orthodontic substitution, an autotransplantation, a tooth-supported restoration, or a single-tooth implant, there are a number of esthetic factors to consider in the final outcome of the treatment. These include symmetry, morphology, shade, width, length, angulation, thickness, and gingival architecture of the replacement tooth or teeth. Other considerations that should influence the treatment planning process include the age and dental/maturational development of the patient at the time of diagnosis of agenesis or tooth loss, the amount of time-lapse between the orthodontic treatment and the definitive restoration, as well as the stability or longevity of the final result. There have been numerous advances in orthodontic positioning,[1] tooth reshaping,[2,3] and restorative treatment through hybrid composite or porcelain laminate veneers that make tooth substitution or autotransplantation viable esthetic options. In the context of a preteen patient, it becomes apparent that replacement of a missing tooth in the esthetic zone with a natural tooth through substitution or autotransplantation most often yields the best long-term solution.

Part 1: Canine Substitution in Cases of a Missing Maxillary Lateral Incisor

The maxillary lateral incisor is the second most common congenitally missing tooth.[4] The patient's age and dental development, malocclusion, canine color/morphology, and smile line, as well as the longevity and long-term periodontal health of treatment and financial resources of the patient, influence whether space closure or substitution should be the treatment plan of choice.

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Age and Dental Development

Agenesis of a maxillary lateral incisor is often diagnosed by the patient's pediatric or family dentist, and the patient is referred to an orthodontist before all the permanent dentition has erupted. One advantage of canine substitution is that final restorative treatment can be completed soon after orthodontics is finished in the early teen years. Furthermore, the presence of natural tooth to induce alveolar bone formation during these growing years is a great advantage. If space opening and a single-tooth implant are planned, then a young patient is faced with the cumbersome challenge of esthetically maintaining the intercoronal as well as the inter-radicular space through their growing years.[5,6] Additionally, a bone graft is usually required before implant placement, introducing further morbidity and expense to the procedure.

Malocclusion

Historically, those patients with missing lateral incisors who presented with maxillary dentoalveolar protrusion and/or an Angle Class II molar relationship and minimal crowding in the lower arch were considered the best candidates for canine substitution. This was owing to the reduced orthodontic treatment needed to achieve an occlusion in which the canine substitutes for the missing lateral incisor and the premolar substitutes for the canine. Another type of malocclusion that has historically lend itself favorably to a substitution treatment plan is one in which there is a Class I molar occlusion with sufficient crowding in the lower arch to justify extraction of mandibular premolars. However, temporary anchorage devices have provided clinicians with the necessary anchorage to predictably protract Class I molars into a Class II relationship, thereby allowing clinicians to comfortably offer canine substitution to patients with a wider range of malocclusions. Critics of orthodontic substitution often claim that the inability to achieve canine guidance with this procedure might cause occlusal problems. However, several studies have examined patients treated by substitution versus prosthetic tooth replacement and found no significant difference in either occlusal function or temporomandibular dysfunction.[7-9] To exclude the dental implant from the esthetic zone, many cases lend themselves to anterior space closure and canine substitution, leaving the implant space at the first or second premolar location, where there are lower esthetic demands.

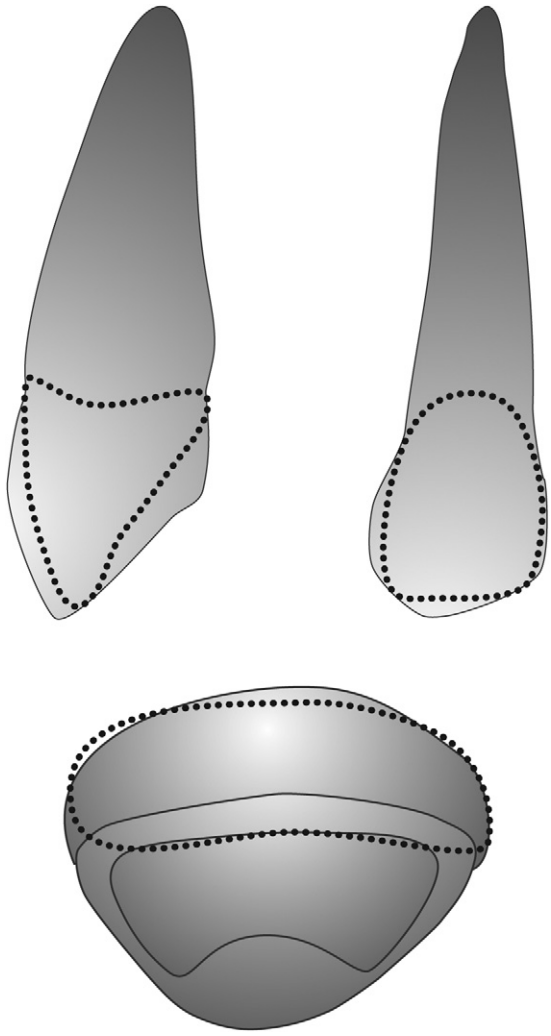

Figure 1. Proximal, facial, and occlusal view of enamel reduction and composite addition suggested to achieve ideal occlusion and esthetics.

Size, Shape, and Color of the Canine

When substituting a canine for a lateral incisor, the anterior interarch tooth-size relationship must be considered, as canines are typically wider than lateral incisors. Additionally, they are thicker faciolingually, which can also affect anterior tooth-size relationships. Often, significant reduction of the lingual surface of the canine is

Figure 2. Pretreatment photo of patient missing the maxillary right lateral incisor. (Color version of figure is available online.)

required to match the faciolingual thickness of a lateral incisor (Fig 1). Subsequently, when the premolar is substituted for the canine, the difference in widths of these teeth should be considered. The best way to ensure an esthetic and functional outcome is to perform a diagnostic wax setup.

Not all canines lend themselves equally to lateral substitution. Canines that are smaller, flatter facially, and lighter in color are more ideally suited than those that are large, facially convex, and more saturated with color. However, even the more challenging canines can be made to look esthetically pleasing if proper technique is followed. Large canines can be reduced in all dimensions, but reshaping the canine is not without some risk. Possible complications include increased sensitivity and darkening of color due to thinning of enamel. Zachrisson and Mjör[10] have shown that extensive reshaping of teeth through grinding with an ample water spray can be safely performed; however, the most conservative reshaping that will achieve an ideal esthetic result is desired. Often, this requires a combination of enamel grinding in some areas combined with the addition of composite resin in others. This technique involves flattening the incisal edge of the canine. If needed, the mesial and distal surfaces are reduced (Figs 2-4), taking particular care not to introduce an interproximal ledge that could harbor plaque or irritate the interproximal tissue. Additionally, the convex facial surface of the canine is flattened (Figs 5, 6), with particular care taken not to darken the tooth due to excessive thinning of the enamel in this area. The mesioincisal and/or distoincisal corners are commonly restored with composite resin (Figs 7, 8), but equally important and often overlooked is the development of a mesiofacial line angle (Fig 9). Note that the conversion of a canine to a lateral incisor should be done before orthodontic bracket placement (Figs 9, 10) when possible. This will allow the early establishment of mesiodistal and faciolingual axial inclinations as well as incisogingival position of the tooth that

Figure 4. After proximal reduction. (Color version of figure is available online.)

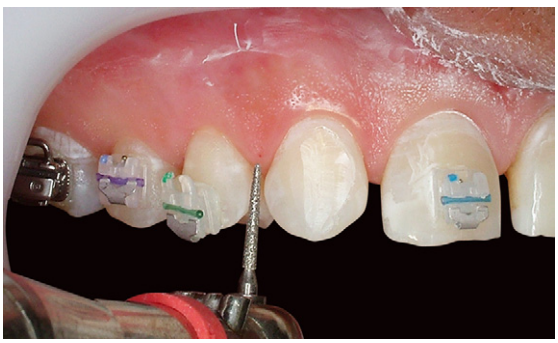

Figure 3. Before proximal reduction. (Color version of figure is available online.)

Figure 5. Before facial reduction. (Color version of figure is available online.)

Figure 6. After facial reduction. (Color version of figure is available online.)

Figure 7. Initial placement of composite on the mesioincisal and distoincisal corners. (Color version of figure is available online.)

Figure 8. Completed composite restoration of maxillary lateral incisor. (Color version of figure is available online.)

most closely emulates a lateral incisor (Figs 11, 12).

Longevity of Treatment

With a committed interdisciplinary approach from a talented team of specialists, a single-tooth implant in the anterior maxillary region can

Figure 9. Facial view of bracket placement after restoration. (Color version of figure is available online.)

Figure 10. Occlusal view of bracket placement after restoration. (Color version of figure is available online.)

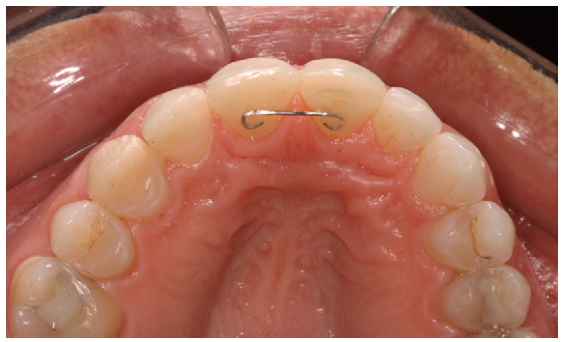

Figure 11. Occlusal view after completion of orthodontic treatment. (Color version of figure is available online.)

Figure 12. Facial view after completion of orthodontic treatment. (Color version of figure is available online.)

have an esthetic result at the time the restoration is completed. In an agenesis patient, implant placement and restoration most often occurs in the late teens. However, maturational changes in hard and soft tissue can occur after the late teen years, which can adversely affect the esthetics of the implant restoration relative to the surrounding natural dentition. These changes include a natural uprighting of maxillary and mandibular incisors,[11] as well as continued vertical changes of the maxillary anterior teeth.[12-16] One study found blue coloring of the gingiva in >50% of single-implant crowns at 4-year follow-up appointments due to thinning of the facial alveolar bone overlying the gingiva.[17] Gingival recession and exposure of a dark crown margin or implant head are also a possibility. A paramount advantage of having all-natural teeth in the esthetic zone is that the substituted or autotransplanted teeth experience the same maturational soft- and hard-tissue changes as the adjacent natural teeth. Robertsson and Mohlin[9] compared final outcomes of 50 patients who had agenesis of a lateral incisor. Of these, 30 patients had received orthodontic substitution and 20 had space opening for tooth-supported prosthetic replacement. The authors found that space-closure patients were more satisfied with their treatment results, had less plaque and gingivitis, and better periodontal health around their natural tooth versus a tooth-supported prosthetic replacement.

Smile Line

Many patients display the gingival margins of their maxillary anterior teeth on a full smile, and some have excessive gingival display. This can be due to a hypermobile lip, vertical maxillary excess, dentoalveolar extrusion, altered passive eruption,[18,19] or any combination thereof. Owing to the highly visible nature of the gingival margins in the esthetic zone, the authors feel that the placement of dental implants in the esthetic zone on young patients with high smile lines is contraindicated when other options such as substitution, autotransplantation, and esthetic tooth-supported restorations exist.

Financial Resources of the Patient

A number of patients seeking dental implant replacement for a missing lateral incisor will first require a bone graft. This procedure incurs a substantial expense and has some morbidity. This cost, along with the expense of the dental implant and crown, can amount to thousands of dollars per replacement tooth. Orthodontic canine substitution for a missing lateral incisor can save the patient a substantial amount of money per missing tooth, while providing a result that is immediate, long-lasting, and adaptive to the body's natural maturational process.

Part 2: Substitution of the Premolar for the Cuspid

One of the most commonly overlooked procedures in achieving an optimal result when substituting a canine for a missing lateral incisor is to apply the same stringent esthetic requirements when substituting a premolar for a canine. The technique described by Rosa and Zachrisson[1,20] is a seminal contribution to the body of knowledge on this subject. First, one should examine the gingival margins of the substituted premolar tooth, the central incisors, and the contralateral cuspid. These gingival margins should all be level with each other. The vertical gingival margin discrepancy and the amount of intrusion necessary to achieve a symmetric gingival margin can then be measured (Fig 13). This measurement determines the amount of the occlusal offset in bracket position on the substituted premolar, and the occlusally offset bracket can then be accurately bonded from the onset of orthodontic treatment. In this manner, the premolar can most efficiently be intruded throughout the leveling and aligning process (Figs 14, 15). The occlusal edge of the premolar can later be lengthened back into occlusion through a composite or porcelain restoration (Fig 16), thereby rendering a tooth that more closely resembles a canine in length, width, morphology, and gingival margin position (Figs 17, 18).

Part 3: Lateral Substitution in Cases of a Missing Maxillary Central Incisor

Most traumatic dental injuries occur in the preteen years, with the central incisor being the most commonly avulsed tooth.[21,22] When an incisor is lost, its ability to induce growth of the surrounding alveolar bone is also lost. Therefore, in the esthetic zone of a young and growing

Figure 13. Note gingival margin discrepancy between maxillary central incisors and right first premolar substituting as canine. This difference determines the amount of intrusion needed and, therefore, the amount of occlusal offset during initial bracket placement of the premolar. (Color version of figure is available online.)

Figure 14. Premolar was intruded during the leveling process owing to occlusal bracket position. (Color version of figure is available online.)

Figure 15. Note gingival margin of premolar is now level with gingival margins of central incisors. (Color version of figure is available online.)

Figure 16. Occlusal edge of facial cusp of premolar is restored with composite to emulate a canine. (Color version of figure is available online.)

Figure 17. Orthodontic bracket is rebonded in a passive position. (Color version of figure is available online.)

Figure 18. Note the symmetry of the gingival margins of the substituted premolar to the contralateral cuspid and central incisors. (Color version of figure is available online.)

patient, it is critical to replace a missing tooth with a natural tooth that can continue the process of bone induction through their teen years. In the case of a missing central incisor, one solution is to transform the lateral incisor into a central incisor with composite resin or porcelain laminate veneer restoration and orthodontically move it into the central position (Figs 19-22). This orthodontic movement is best achieved by pushing the transformed lateral into the central position with a compressed open coil spring. By careful use of push mechanics on a stopped arch wire, a clinician can avoid the common error of shifting of the maxillary midline toward the side of the missing tooth. This unwanted shifting is often observed when the diastema closure is attempted using pull mechanics with elastic chain. On closure of the central diastema, the case can now be considered as missing a lateral incisor, and the aforementioned techniques on converting a canine into a lateral incisor and transform-

Figure 19. Maxillary left central incisor of a 12-year-old boy was traumatically avulsed. (Color version of figure is available online.)

ing a premolar into a canine can subsequently be followed.

Part 4: Autotransplantation in the Case of a Traumatically Avulsed Central Incisor

Autogenous tooth transplantation, or dental autotransplantation, is the extraction of a donor tooth from its original erupted or impacted site to a prepared recipient site or extraction socket in the same individual. One of the most successful and common applications of autotransplantation is the replacement of a missing maxillary incisor with a premolar.[23-27] As previously mentioned, most traumatic dental injuries occur in the preteen years, with the central incisor being the most commonly avulsed tooth. Unlike an implant, a successful autotransplantation of one's own tooth will induce growth of bone and surrounding tissues and will re-establish a normal alveolar process as the patient continues to grow and mature. If autotransplantation is chosen, orthodontic treatment will need to be timed such that the recipient site will be ready when the donor tooth has two-thirds to three-fourths

Figure 20. Maxillary left lateral incisor restored with composite resin to emulate a central incisor. (Color version of figure is available online.)

Figure 21. Brackets placed on maxillary central "incisors." (Color version of figure is available online.)

root development.[25,27-29] Fortunately, this stage of root development usually occurs between the ages of 9 and 13, which is the same age as most traumatic dental injuries resulting in loss of an anterior tooth (Figs 23, 24).

Donor tooth selection starts with measuring the crown size of the contralateral incisor. A mandibular second premolar, owing to its crown size, root shape, and root diameter, is often the best donor tooth to replace a missing central incisor. Although a case is ideal in which extractions in the lower arch are beneficial to relieve crowding, not all cases require mandibular extractions for orthodontic reasons. Donating a mandibular second premolar makes for easier orthodontic mechanics during a temporary anchorage device–assisted closure of the mandibular space on an otherwise nonextraction case.

The autotransplantation procedure[29] involves preparation of the recipient site with surgical burs, much like an implant site. Next, the donor tooth is carefully harvested, patiently and meticulously, ensuring that the entire dental follicle is intact and undamaged. The donor tooth is then placed in the recipient site, paying particular

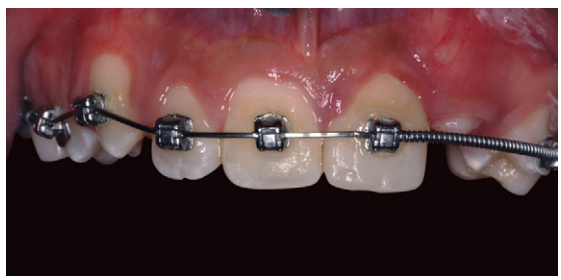

Figure 22. Central diastema closed with push mechanics through an open coil spring. This is critical to not shift the maxillary midline. Patient can now be treated as if he is missing a lateral incisor. (Color version of figure is available online.)

Figure 23. Maxillary right lateral incisor of a 9-year-old boy was traumatically avulsed. (Color version of figure is available online.)

Figure 24. Panoramic radiograph on initial examination.

Figure 25. Space was opened at the recipient site and maintained until the donor tooth achieved two-thirds root development. (Color version of figure is available online.)

attention that there is no binding, impinging, or compression of the periodontal ligament and the tooth should be out of contact with the opposing dentition. It is then sutured into place and stabilized with a light wire splint to allow only physiological movement. Ideally, the recipient site should be slightly wider than the donor tooth (Figs 25, 26), and the remaining proximal space should be distributed such that one-third of the space lies mesially and two-thirds of the space lies distally (Fig 27). The facial surface of the donor tooth should also be placed approximately 0.5 mm lingual to the facial surfaces of the adjacent teeth to allow space for composite

Figure 26. Panoramic radiograph showing two-thirds root development of the mandibular left second premolar donor tooth.

Figure 27. Mandibular left second premolar was autotransplanted into the recipient site. (Color version of figure is available online.)

Figure 28. On the same day as the autotransplantation surgery, the donor tooth was splinted to adjacent teeth with a thin coaxial cable wire to allow physiological movement. (Color version of figure is available online.)

restoration (Figs 28, 29). The patient is placed on a chlorhexidine rinse and soft diet for 6 weeks as a precautionary measure, and instructed to gently clean the area with a cotton swab rather than a toothbrush. While it is the position of some authors to recommend healing for 3-4 months before restoration or application of orthodontic forces, the composite build-up and application of extremely light orthodontic forces can be successfully begun as early as 6

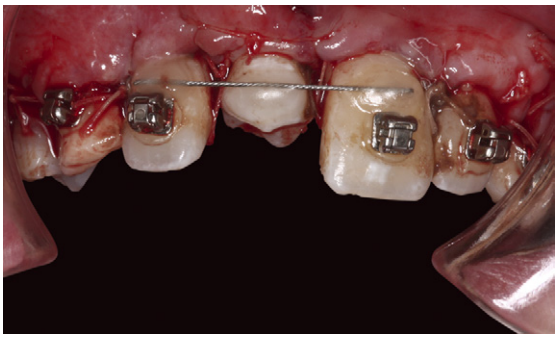

Figure 29. Facial view of the splinted donor tooth. (Color version of figure is available online.)

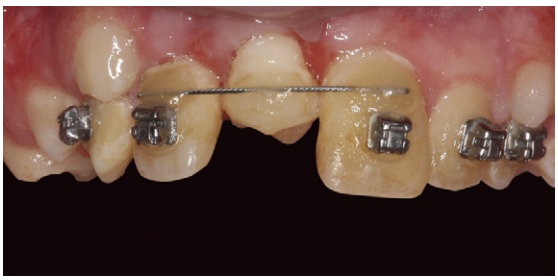

Figure 30. Six weeks of healing allowed the soft tissue to mature and the tooth to stabilize. (Color version of figure is available online.)

Figure 31. Stabilizing wire was removed. (Color version of figure is available online.)

Figure 32. Donor tooth was built up with composite resin to emulate a maxillary right central incisor. (Color version of figure is available online.)

Figure 33. Bracket was placed on the new tooth and 0.014" × 0.025" NiTi orthodontic wire engaged. (Color version of figure is available online.)

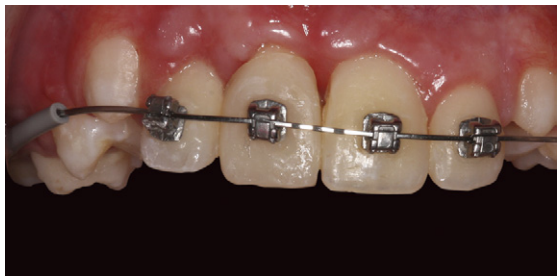

Figure 34. Final alignment of donor tooth. Further tissue maturation will occur over time with good oral hygiene. (Color version of figure is available online.)

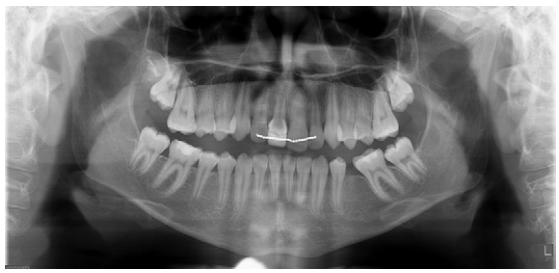

Figure 35. Panoramic radiograph 12 months after autotransplantation.

weeks if necessary due to scheduling constraints (Figs 30-35).

The risks of autotransplantation include ankylosis and pulpal necrosis with either inflammatory resorption or replacement resorption. Most likely, these complications are a result of damage to the periodontal ligament of the donor tooth during extraction. Even in the event of an unsuccessful autotransplantation, the donor tooth will have facilitated alveolar bone induction necessary for an osseointegrated implant once the child's growth has been completed.

However, when fastidious care is taken during the surgical technique, long-term survival rates of 98%-100% have been reported.[27,29,30] With such high success rates and predictable esthetic results, autotransplantation of a mandibular premolar should be one of the primary methods used to replace a maxillary anterior tooth.

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