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Orthodontic Management of Patients with Congenitally Missing Permanent Teeth

SUMMARY

Dental agenesis is one of the most common developmental anomalies in humans. It occurs as part of a genetic syndrome or as an isolated sporadic or familial finding. Third molars, second mandibular premolars and maxillary lateral incisors are the most frequently targeted teeth of the permanent dentition. Clinically, patients with congenitally missing permanent teeth seeking treatment present with unesthetic diastemas, midline deviation and tilting of adjacent teeth in the edentulous areas. The impact of tooth agenesis reflects on esthetics, function, psychological and social well-being of the individuals affected. Orthodontics can contribute to the treatment plan selected by rearranging the present teeth so as to open spaces for prosthetic restorations or close spaces by reshaping teeth if needed. Following orthodontic space opening/maintaining, the usual alternatives involve single implants, two-(cantilever) or full coverage-(cantilever) prostheses. Less frequently, the treatment modality of autotransplantation is proposed with a good esthetic result but feasible only in young patients where the roots of the premolars are still developing. In orthodontic space closure, treatment is accomplished sooner without waiting for the completion of growth of the patient. Depending on various factors such as the malocclusion, the dento-skeletal profile, the smile line, the space requirements, the teeth missing, the periodontal issues, the age of the patient and any financial issues, the clinician will determine the most appropriate treatment approach. The final esthetic and functional result should resemble an intact natural dentition.

Key words: Congenitally Missing Permanent Teeth, Dental Agenesis, Hypodontia, Aplasia, Oligodontia, Orthodontic Space Closure, Orthodontic Space Opening, Autotransplantation

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Introduction

Congenitally missing permanent teeth represent a challenge to the clinician in the daily practice. Unfavorable position of the existing teeth within the dental arches can affect esthetics as well as function. Whether it involves young patients at an early age or adults visiting the office later in their life, the practitioner is frequently asked on how to proceed for the benefit of the patient. The question that arises regarding the treatment approach is whether to open existing/lost space for the replacement of the missing tooth with prosthetics/osseointegrated implants or even autotransplantation or to close space orthodontically and reshape teeth if needed. Selection of the optimal treatment option depends on various parameters involving dento-skeletal profile, type of malocclusion, space issues, age and cooperation of the patient, periodontal health as well as financial issues.

Agenesis of permanent teeth can be of syndromic or non-syndromic genetic origin. Its severity varies based on the number of missing teeth in the arches. Accordingly, different terms are applied in the literature to describe numeric dental anomalies. Hypodontia is referring to the situation where agenesis or absence of less than six teeth exists. Oligodontia is referring to the absence of six or more than six teeth. Anodontia is used for complete

absence of teeth[1]. This paper is only going to discuss non-syndromic absence of permanent teeth and the contribution of Orthodontics in the management of such cases.

In the literature, large differences in the prevalence of dental agenesis have been reported, due to the variability of the sample size examined. The prevalence for both sexes is higher in Europe (males 4,6%; females 6,3%) and Australia (males 5,5%; females 7,6%) than for North American Caucasians (males 3,2%; females 4,6%)[2]. Based on gender, females seem to be 1,37 times more susceptible to dental agenesis than males.

According to the meta-analysis of Polder *et al.*[2], unilateral occurrence of dental agenesis is more common than the bilateral one. The overall prevalence of agenesis is comparable in both jaws, but differs with respect to the tooth type.

Regarding the agenesis of individual teeth and with the exception of third molars being first on the list (incidence varying up to 30%)[3], mandibular second premolars are the most affected teeth (2,9-3,22%)[2]. The latest are followed by the maxillary lateral incisors (1-3%)[2,4], the maxillary second premolars (1,39-1,61%)[2] and the mandibular central incisors (0,25-0,35%)[2].

Etiology of congenitally missing permanent teeth

Tooth agenesis can be part of a genetic syndrome or an isolated sporadic or familial finding. Although there are over 300 genes identified to play a role in mouse odontogenesis, the molecular basis of tooth development in humans is largely undefined[5]. Mutations of only three of these genes namely being MSX1, PAX9 and AXIN2 have been identified and associated with the familial non syndromic, autosomal dominant tooth agenesis[3,5-13].

MSX1 (muscle segment homeobox 1) and PAX9 (paired box 9) are transcription factors and their mutations are involved in familial tooth agenesis, especially where multiple posterior teeth are missing[5]. AXIN2 (axis inhibition protein 2) is associated with a less tooth-specific type that involves almost any permanent tooth except for the upper central incisors[5].

Besides genetic background, environmental factors have also been implicated with tooth agenesis. Use of thalidomide[14,15], chemotherapy and radiotherapy treatment in early infancy[16,17] have been associated with hypodontia. Maternal health during pregnancy did not seem to be related to expression of hypodontia[18]. However, rubella infection during this time could cause tooth agenesis in the developing child[19]. Finally, exposure to smoking and alcohol have not been proven to be responsible for hypodontia, despite the fact that they have been suggested as risk factors[10,20].

Impact of tooth agenesis

Depending on the patient's age and the type of dentition (whether mixed or permanent), the clinician is usually dealing with unpleasant spaces at the areas of teeth absence, asymmetry and midline deviation to the affected side, drifting of teeth, crown inclinations between adjacent teeth, interdental gaps and reduced perimeter of the arches affected.

Concern has been expressed also regarding the posterior areas where congenitally missing permanent teeth can create initially localized spacing that may be worsened with time. Generalized spacing and rotations of adjacent teeth, as well as overeruption of opposing teeth and occlusal non-working interferences could be some of the characteristic features in situations of missing posterior teeth. Additionally, development of increased overjet and overbite, retrusion of the upper and lower incisors and midline shifts have been reported in the literature[21].

Besides esthetics, there are also functional, psychological, as well as social problems related to congenitally missing permanent teeth. Oral-health-related quality of life (OHRQoL) measures are often applied to assess the impact on health and well-being of individuals with hypodontia[22]. Unfortunately, only a few such studies have taken place. The severity of the patients' complaints was associated with the extent of the problem with respect to the number of missing teeth. In case of presence of retained deciduous teeth, the actual problem was covered[23].

Orthodontic Management

The contribution of Orthodontics in the treatment planning of patients with congenitally missing teeth is significant. In a young patient, spaces due to absence of teeth are crucial to deal with, not only for the esthetics, but also for function in the long-term. The orthodontist is called to decide whether opening/maintaining or closure of spaces is more beneficial to the patient. In cases of absence of successor teeth, extraction of the retained deciduous teeth to enable migration of adjacent teeth may be useful. The appropriate decision is made after taking into consideration the patient's malocclusion, the growth pattern, the profile, the crowding, the esthetic smile line and the morphometric features of the teeth adjacent to the missing ones.

An important factor for the decision of the maintenance or not of the deciduous tooth with missing successor is its prognosis. In the case of a healthy deciduous tooth, its retention in the dentition preserves the necessary space for future rehabilitation once lost. When the width is larger than needed, reduction and possible preservation with a temporary crown might be recommended till the appropriate time for the permanent prosthetic restoration. If the deciduous tooth has poor prognosis, characterized by root resorption, ankylosis, non restorable dental caries or pulp pathology, its maintenance in the arch becomes problematic. In so, the option of

extraction of the deciduous tooth is selected and the orthodontic management is modified accordingly.

A) Orthodontic space opening/maintaining

Since in cases of missing teeth, spaces are unevenly distributed, the goal is to establish proper rearrangement of existing teeth, while treating the patient for his/her malocclusion. Generalized spacing and rotations adjacent to the missing teeth are often seen. Thus, space management, uprighting and aligning may be required before any restorative treatment can take place. Another factor that has to be taken under consideration is the available bone volume of the edentulous space and the necessity for creation of bone via orthodontic movement of adjacent teeth, when in deficiency. In posterior areas of the dental arches, additional parameters that have to be considered are the distance of the retained deciduous molars from the occlusal plane (possible infra-occlusion declaring presence of ankylosis), the condition of the retained deciduous molars (degree of root resorption, tooth decay, pulp pathology) and the presence of the respective third molar.

Space opening is indicated in cases of Angle Class I molar relationship, Class III with concave facial profile and in cases in which the canine recontouring is not recommended[24]. Recontouring of the canines should be done to eliminate the labial and proximal convexities, the lingual cingulum and to form the mesioincisal and distoincisal edges. When, however, their size is relatively large or there is a significant colour difference, canine recontouring is not recommended. Patients with upright maxillary incisors that need to be protruded, to be inclined labially, to provide additional lip support, and to improve/correct anterior crossbites are appropriate candidates[25]. Patients with accentuated alveolar protrusions and soft tissue convexity are contra-indication for orthodontic space opening[26].

Determination of the amount of space needed in the event of orthodontic space opening is crucial. When the problem of tooth agenesis concerns the front area, and more frequently the lateral incisor region, there exist four different methods that assist in this measurement:

a) The rule of golden proportion among the anterior teeth where the perceived mesiodistal dimension of an anterior tooth follows a ratio of 1:0.618 with the tooth next to it. In other words, the width of a lateral incisor should be equal to 61.8% of the width of a central incisor[27,28]

b) Applicable only in cases with unilateral agenesis, with the measurement of the contralateral lateral incisor size[28,29]. However, this is difficult when the contralateral tooth is hypoplastic peg-shaped or worn

c) The Bolton analysis offers valuable information for the anterior region with the fraction of the total mesiodistal width of the lower anterior teeth to the total mesiodistal width of the upper anterior teeth being 0.78 ideally[30]

d) The construction of a diagnostic wax-up can predict the optimal space required[28].

When the congenitally teeth missing are the second mandibular premolars, maintaining the deciduous second molars in the arch is a viable option. In the literature, it is stated that many deciduous molars can be retained in the dental arches at least until the early twenties[31]. Ideally, these primary teeth have to be slenderized (reproximated of their mesiodistal parts), in order to limit their size to the dimension of the second premolars and prevent an antero-posterior arch-length discrepancy. This procedure can be initiated from the age of 8 to 9 and can be performed until the age of 14 to 15[32]. If the retained deciduous molars are moved orthodontically, there is a risk of severe root resorption[33]. The orthodontist will decide either to compromise with an "end-on" molar relationship by leaving the deciduous molars intact or to risk potential root resorption by slenderizing them[31,33]. In the literature, there are many reports of primary posterior teeth surviving until the patient reaches the age of 40-60 years[32,33]. The advantage of maintaining the primary molars is that, in this way, the alveolar bone is maintained both vertically and buccolingually till the time of root resorption and exfoliation of the retained teeth. Another approach that has been reported in the literature is the hemisection of the deciduous molars (following root canal therapy of the root to be retained), allowing the adjacent tooth to drift to the space created[34,35].

Once the orthodontic role has been accomplished, in the scenario of opening/maintaining the spaces of the missing teeth, prosthodontic intervention is taking place. Undoubtedly, the skeletal age of the age is the predominant factor on when the restorations are taking place. The possible alternatives include: i) single-tooth implant, ii) two-(cantilever) or 3-unit resin-bonded prostheses, iii) full coverage-(cantilever) or 3-unit fixed dental prostheses, iv) autotransplantation.

(i) The endosseous single-tooth implant is the most conservative approach when opening / maintaining of spaces is selected by the clinician

For the case of a missing lateral incisor, when a standard-diameter implant (3.75 mm) is planned to be placed, the minimal mesiodistal space required should be approximately 7 mm[36]. This space is necessary to provide at least 1.5 mm on each side (mesial and distal) between the implant platform and the adjacent teeth for the development and preservation of the papilla[36,37]. If the mesiodistal space is less than 7 mm, a smaller-diameter implant can be used.

Uprighting the roots of the teeth adjacent to the edentulous space is extremely important and in so, the contribution of Orthodontics is valuable. Periapical radiographs taken, while in treatment, offer significant

information and guidance. Orthodontic treatment is aiming to a successful preparation of the site of the implant that is going to replace the missing tooth, with parallelism of the roots of adjacent teeth and provision of proper root proximity.

A minimum of 1 mm of bone should exist between the implant and the adjacent roots[38]. The minimum incisogingival and buccolingual bone should be 10 and 6 mm respectively[29]. If the buccolingual dimension is insufficient, a bone graft may be necessary. When a canine erupts next to the central incisor, its buccolingual width creates a sufficient width of the ridge. After eruption, the canine can be distalized orthodontically and, in so, establish a proper buccolingual width of the alveolar ridge following stretching of the periodontal ligament by the root movement[38]. If an implant site is developed with this kind of orthodontic guided tooth movement, the buccolingual width remains stable[39].

Despite the fact that single dental implants present high survival rates, long-term implications often occur[40]. Some of these may include blue coloring of the labial gingiva, exposure of metal or porcelain abutment over time, recession particularly of the distal papilla and increasing rates of infraocclusion even after the end of growth[40-44].

(ii) Two-(cantilever) or 3-unit resin-bonded prostheses is the most conservative treatment option among the tooth-supported restorations

The most common type of resin-bonded prostheses is based exclusively on adhesion to secure retention[28]. There are certain prerequisites for the success of this prosthetic option, such as: a) shallow anterior overbite, b) absence of parafunction, c) non proclined, non mobile, moderately thick and translucent in the incisal one-third abutment teeth.

In the literature, there are various studies regarding the longevity of the resin-bonded prostheses. Besides debonding as the most frequent complication, fractures and slight grayness of the abutments are also reported[45-47].

In the systematic study by Pjetursson *et al*.[45] on earlier types of resin-bonded prostheses, a 5-year survival rate of 87,7% was demonstrated. Aggstaller *et al*.[48] reported a survival rate of 77% after a 10-year follow-up period without including the rebonded or repaired restorations while Ketabi *et al*.[49] found a mean survival rate better than 69% without including the rebonded restorations after a 13-year observational period.

(iii) Full coverage-(cantilever) or 3-unit fixed dental prostheses is considered as the conventional and least conservative of all tooth-supported restorations

Indications for its use include a) the replacement of an existing fixed partial denture, b) the presence of adjacent teeth requiring rehabilitation due to extensive caries, fractures and/or discolourations, c) the morphology of the adjacent teeth need to be altered for improvement of dentofacial esthetics and d) the need for control of exerted occlusal forces[28].

Tan *et al*.[50] showed that the mean survival rate of conventional fixed partial dentures is clearly greater than the mean survival rate of adhesive fixed partial dentures. A systematic review by Sailer *et al*.[51], reported a 5-year survival rate of 94,4% for metal-ceramic restorations and 88,6% for all-ceramic restorations. For all-ceramic restorations, technical complications noted were marginal discolouration (15,3%) and porcelain chipping (13,6%), with the most serious being the framework fracture. In a 10-year observational period, Sharma[52] reported survival and success rates of 92% and 81,1% reported respectively for full coverage fixed partial dentures.

(iv) Autotransplantation refers to the technique of transplanting embedded, impacted or erupted teeth from one site into another in the same individual

It can be performed in both the anterior and posterior regions of the dentition. Successful autotransplantation is a viable treatment option that can offer many advantages in a growing patient, including a normally functioning periodontium, proprioception and preservation of alveolar bone volume[53,54]. Even in the worst scenario of failure of the autotransplantation, the bone and soft tissue conditions would still be likely to be favorable for subsequent implant treatment. Since autotransplantation supports bone regeneration[55], even when the transplant is lost, the normal alveolar process is better prepared for a dental implant[56].

The appropriate timing for autotransplantation is as soon as the roots of the teeth to be autotransplanted have developed the two-thirds to three-fourths of their definitive length[57-59]. Future root growth is likely to be limited or inhibited if Hertwig's epithelial root sheath is damaged[60]. When any damage in the periodontal ligament is avoided by the surgeon, the possibility of ankylosis is minimized. Care must be taken for sufficiency of space on the mesial and distal sides of the graft. During the fixing period, there should be presence of physiologic mobility of the graft. This minor movement reduces the risk of ankylosis and any adverse effects on the periodontal ligament pulp healing[61,62]. Any premature contacts/interferences should be limited between the transplant and the opposing teeth. An observational period of 3 to 4 months is advisable to intervene after the autotransplantation before the initiation of any orthodontic treatment to the autotransplanted tooth[59].

When autotransplantation is performed in the anterior region of the dentition, the requirements are challenging. The overall aesthetics are dependent upon the alveolar ridge volume, the soft tissue thickness, the lip position upon smiling and the quality and appearance of the restorations[63,64]. When the periodontal ligament is successfully preserved in the autotransplantation, this represents the esthetic advantage of inherent potential for

bone induction and re-establishment of a normal alveolar process, thus contributing to soft tissue preservation[65]. For the growing adolescent patient, this keeps future rehabilitation options open. In the case of a premolar transplanted in the anterior region, its crown (usually positioned with a 90^0 rotation) should be modified to resemble and function as an anterior tooth. Direct composite resin buildups will be performed, replaced later in time by porcelain laminate veneers[59]. The survival rate and success rate are very high after a mean follow-up period of 26,4 years, namely being 90% and 79% respectively[66]. In a shorter follow-up study of 4,8 years, the success rate of transplanted premolars in the anterior region was 100%[67].

Autotransplantation for the posterior region does not generally demand any prosthodontic procedures to ameliorize dental aesthetics[53]. In so, the cost-benefit perspective of this treatment approach is improved. Jonsson and Digurdsson reported a 92,7% success rate of 40 transplanted premolars in premolar sites during a mean observation period of 10 years and 4 months[68]. After a mean of 1,76 years of follow-up period, Mensink *et al*.[69] found a 100% survival rate of 44 transplanted premolars.

In the event that the deciduous retained tooth is lost due to root resorption or is extracted because of ankylosis, the alveolar bone volume is reduced with time. Even an uncomplicated extraction would lead to reduction of the bone mass by 18-25% and might jeopardize future implant therapy[70]. Ostler and Kokich[71] estimated the long-term changes in the width of the alveolar ridge after the extractions of the primary mandibular second molars and found a 25% decrease of the ridge within 3 years post-extraction. The rate of decrease diminished to 4% over the next 3 years. Interestingly, greater buccal ridge resorption (74%) was seen compared to the lingual side.

B) Orthodontic space closure

In patients with congenitally missing maxillary lateral incisors, canines frequently show a mesial pattern of eruption, with a final position adajacent and parallel to the central incisors in the dental arch[72]. Such a condition favors canine substitution. There are several studies reported in the literature regarding the advantages of orthodontic space closure[24,73,74]. The main advantage is that completion of treatment takes place early in adolescence without any necessity for future prosthetic restorations. Costly procedures involved in prosthodontic rehabilitation are avoided, as well as potential risk of complications of prosthodontic intervention. Additionally, there is no need for waiting years until the "end of growth" to replace the missing tooth. Periodontal problems are not developed in space closure since the tooth has moved along with its bone and surrounding tissues. More specifically, the alveolar bone height in the actual main region is maintained and clear and natural gingival margin is achieved. This margin will change over the lifetime due to aging or other reasons (mechanical, periodontal), taking on a natural look[75].

Orthodontic space closure by mesial repositioning of the canine is followed by reshaping in order for the canine to resemble a lateral incisor. This treatment approach is indicated[76] in cases of: a) Angle Class II malocclusion with no crowding in the mandibular arch, b) Angle Class I with severe crowding in the lower arch or incisor protrusion when extractions are needed, c) balanced, relatively straight or even mild convex profile, in conjunction with normally inclined teeth and minimal or no space available in the maxillary arch, and d) anterior maxillary teeth severely protruded or tipped labially. The final occlusion accomplished in lateral excursive movements is anterior group function and not canine guidance[77,78].

The disadvantages of space closure and anatomic recontouring of the canines to the shape of lateral incisors have to do with the necessary interventions in their size, shape and colour so as to substitute ideally the lateral incisors. Since a canine is broader than a lateral incisor by approximately 1,5 mm[78], it needs reduction of its mesiodistal dimension and leveling of the incisal edge, elimination of the labial convexity and recontouring to resemble a lateral incisor. On the other hand, a premolar in the place of a canine requires increase in its incisogingival and mesiodistal dimension as well as elimination of its palatal cusp. Correction of the crown torque of the mesially relocated canines as well as the mesially moved premolars should take place. Differential bracket bonding is usually applied in conjunction with the need for adjustment off-set bends and application of proper torque for the canines and premolars.

Regarding the soft tissue architecture (gums), ideally the gingival margins of the central incisors and canines are at the same level, whereas the gingival contours at the lateral incisors are roughly 1 mm lower than the line between the central incisors and the canines[79]. In orthodontic space closure, when the canine is taking the position of the lateral incisor and the first premolar is moved to the position of the canine, it is, thus, necessary to extrude the canine and intrude the premolar[24]. This movement is balanced by selective grinding of the cusp tip of the canine. By performing a virtual setup for space closure, Lombardo *et al*.[80] evaluated the optimal parameters for final position of the teeth and advised for 1,33 +/- 0,5 mm of selective grinding to the palatal surface of the upper canine, in order to prevent pre-contacts. They also suggested extrusion of the canine by 0,68 +/- 0,23 mm and intrusion of the premolar by 0,56 +/- 0,3 mm, in order to obtain ideal gingival architecture.

Finally, another point that has to be taken under consideration is the colour difference of the canines that are darker than the incisors which becomes even more yellowish with extensive tooth recontouring[74]. In order to overcome this situation, labial recontouring can be

avoided by increasing the palatal root torque of the canine and decreasing occlusally the canine cusp length, which leads to a reduction in the extension of the labial canine convexity. A differential approach might be the tooth bleaching or the prosthetic restorations such as composite build-ups, veneers or all-ceramic crowns[25].

In the posterior region, when the second premolars are congenitally missing, it has been suggested that early treatment may allow spontaneous space closure by guiding tooth eruption[81]. Svedmyr[82] proposed extraction of the deciduous second molar prior to eruption of the first molar in order to stimulate mesial eruption of first molars. However, according to Bergström[83] and Rölling[84], diagnosis of aplasia of a mandibular second premolar in patients under 9 years of age is rarely made. Joondeph and McNeill[85] suggested that in subjects with hypodontia, the deciduous second molar should be extracted early, before the age of 11. In a 4 year follow-up after the extraction of these primary molars, it has been shown that 80% of the resultant space was closed with a mean residual space of 2 mm[86]. In adolescents, space closure is a more appealing solution since there is no need to wait for the completion of growth before a permanent restoration takes place.

The drawback of space closure without the aid of Orthodontics is the appearance of drifting and tipping of the adjacent teeth. In 84% of selected cases, Lindqvist[81] reported closure of space by mesial drift and tipping of the first molar and distal drift and tipping of the first premolar. Extraction of the second deciduous molar after completed root development of the second molar and first premolar often leads to more tipping of these teeth. In a follow-up study of 40 patients, Jonsson and Sigurdsson[68] found that early extraction could produce inclination in 46% of patients with mesial rotation of the permanent first molars and distal drift of the premolar and the canine in 80% of these space closures. The orthodontic treatment of space closure ensures controlled inclination of all the permanent teeth as in an ideal dentition without any congenitally missing teeth.

Conclusions

Early diagnosis of congenitally missing permanent teeth is fundamental in the management of the clinical situation. Scheduled extraction of the deciduous teeth involved can lead to guided eruption of teeth adjacent to the edentulous space. Depending on clinical parameters of the occlusion, such as the dento-skeletal profile, the type of malocclusion and the age of the patient, the practitioner may select to proceed to space opening or closure of the diastemas of hypodontia. When both treatment approaches are indicated, orthodontic space closure is more preferable due to its early completion of the definitive treatment, its superiority in periodontal health, its reduced cost and chairtime in the long-term. Whatever the treatment option is, the interdisciplinary approach involving orthodontics, esthetic dentistry, implantology and prosthodontics can achieve an optimal occlusion and a well-balanced and natural smile overtime.

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