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Maxillary Lateral Incisor Agenesis: An Evidence-Based Review of Diagnosis and Treatment

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ABSTRACT

Introduction. Maxillary lateral incisor agenesis is a common developmental dental anomaly that affect smile aesthetics, occlusion, and periodontal conditions. The main treatment strategies include orthodontic space closure with canine substitution and space maintenance or opening followed by prosthetic replacement.

Aim. The aim of this review was to compare contemporary treatment approaches for maxillary lateral incisor agenesis and to assess their aesthetic, periodontal, functional, and long-term outcomes.

Materials and Methods. A narrative review of the literature was conducted, primarily using the PubMed database. A total of 21 publications addressing the diagnosis and treatment of maxillary lateral incisor agenesis were included in the analysis. Owing to the heterogeneity of the included studies, a qualitative synthesis was performed.

Results. Both orthodontic space closure and space opening followed by prosthetic rehabilitation may provide satisfactory clinical outcomes. Space closure is associated with favorable aesthetic, periodontal, and functional results, whereas implant-supported restorations represent a predictable treatment option in patients who have completed growth, although they may be associated with late aesthetic changes. Resin-bonded bridges remain a conservative alternative to implant-supported treatment. Treatment selection depends on several factors, including the patient's age, skeletal pattern, malocclusion, tooth morphology, bone conditions, and individual expectations.

Conclusions. No single treatment modality can be considered universally optimal for all patients with maxillary lateral incisor agenesis. Management should be individualized and interdisciplinary, taking into account long-term stability, aesthetics, function, and patient preferences.

Keywords: maxillary lateral incisor agenesis; orthodontic space closure; canine substitution; dental implants; resin-bonded bridges.

1. Introduction

Tooth agenesis is a developmental disturbance in which one or more permanent tooth germs fail to develop. Excluding third molars, the maxillary lateral incisors are among the teeth most frequently affected in the permanent dentition. Reported prevalence varies according to the characteristics of the population studied and the diagnostic criteria applied and, in the publications analysed in this review, generally falls within a range of approximately 1% to 5% [1, 6, 7, 16, 17, 20, 21]. The condition may be unilateral or bilateral. Several studies have reported a greater frequency of bilateral absence and a higher prevalence among females [1, 9, 12, 13, 14]. The biological basis of maxillary lateral incisor agenesis remains incompletely defined. Current knowledge supports a multifactorial mechanism in which genetic susceptibility interacts with epigenetic and environmental influences. Genes involved in odontogenesis and discussed in the reviewed literature include PAX9 and MSX1 [5, 12, 16, 19, 20]. The association between agenesis and disturbances in tooth size, shape, or eruption further suggests that, in some individuals, absence of the lateral incisor may represent one component of a broader developmental dental phenotype [1, 12, 15]. Unilateral agenesis creates additional challenges because the contralateral lateral incisor may itself show altered morphology. A small or peg-shaped lateral incisor on the opposite side has been reported relatively frequently, although its prevalence differs across study populations [12, 20]. In such cases, treatment must address not only the missing tooth and available space but also symmetry and proportionality within the anterior segment. The clinical consequences of agenesis extend beyond the edentulous site. Changes in eruption pathways and arch space may contribute to mesial displacement of the canines, spacing, midline deviation, and asymmetry of the anterior dentition [1, 11, 17, 19]. Because the affected region is highly visible during smiling and speech, the condition may also influence self-esteem and psychosocial well-being [5, 8, 9, 11, 19]. Craniofacial characteristics associated with maxillary lateral incisor agenesis have also been investigated. Some studies, particularly those involving bilateral agenesis, have described reduced maxillary dimensions and a tendency toward skeletal Class III relationships [5, 13]. These observations are not consistent across the literature, however, and the presence of agenesis should not be assumed to indicate a specific skeletal pattern [5, 13]. From a therapeutic perspective, treatment generally requires a choice between modifying tooth positions so that the edentulous space is eliminated and preserving or recreating the missing-tooth site for later reconstruction [1, 8, 11, 12, 14, 19, 21]. In the first approach, the canine is moved mesially and adapted to function and appear as a lateral

incisor. In the second, the space is maintained or opened to accommodate an implant-supported crown, a resin-bonded fixed dental prosthesis, or a conventional fixed restoration [1, 2, 3, 11, 19, 21]. Autotransplantation and temporary solutions for growing patients have also been described in selected situations [15, 16, 19]. The decision between these approaches should not be based on the presence or absence of the tooth alone. Relevant variables include age and growth status, malocclusion, skeletal relationships, facial profile, incisor position, canine morphology and shade, gingival display, alveolar morphology, periodontal conditions, and patient expectations [1, 8, 12, 14, 18, 19]. The purpose of this narrative review is to summarize current principles of diagnosis and treatment planning for maxillary lateral incisor agenesis, discuss available treatment modalities, and critically compare their aesthetic, periodontal, functional, and long-term implications.

2. Materials and Methods

The literature was reviewed primarily through the PubMed database using English-language search terms related to congenital absence of the maxillary lateral incisors and its treatment. The terms used included *maxillary lateral incisor agenesis*, *congenitally missing maxillary lateral incisors*, *missing maxillary lateral incisors*, *orthodontic space closure*, *space opening*, *canine substitution*, *prosthetic replacement*, and *dental implants*. Individual terms and combinations of terms were applied according to the clinical question being explored. The initial stage consisted of screening titles and abstracts for relevance. Full texts of potentially pertinent publications were then assessed. Twenty-one publications were ultimately selected for inclusion from 188 publications published within the last five years. The evidence base was methodologically heterogeneous and included clinical and observational investigations, retrospective and comparative studies, case reports, narrative reviews, and systematic reviews. Differences among the publications were substantial with respect to study design, patient characteristics, therapeutic interventions, outcome measures, and duration of follow-up. For this reason, the results were synthesized qualitatively and were not combined in a meta-analysis. When comparable findings were reported in more than one publication, they were integrated into a common narrative interpretation. When results differed, these discrepancies were retained rather than resolved by assumption.

3. Diagnosis and Treatment Planning

Diagnostic assessment should begin by establishing whether the clinically absent tooth is truly congenitally missing. A maxillary lateral incisor may also be absent because of previous trauma, extraction, root resorption, or another pathological process. Confirmation of agenesis therefore requires integration of the patient's history, clinical findings, and radiographic examination [9, 14]. After agenesis has been established, assessment should extend to the entire dentition and occlusion. Particular attention should be paid to space distribution, crowding, canine and central incisor position, interarch relationships, and dental midlines [11, 14, 17, 19]. The management of the edentulous site should support, rather than conflict with, the broader orthodontic objectives. In some malocclusions, mesial movement of the maxillary posterior teeth contributes favourably to correction, whereas in others maintenance of the canine in its natural position is more compatible with the desired occlusal result [14, 19]. The facial profile and soft tissues should be assessed independently of the dental space. Lip position, maxillary incisor display, and the amount of gingiva exposed during smiling are particularly relevant. In a patient with a high smile line, relatively small differences in gingival margin levels or interdental papillary fill may become clinically conspicuous [14]. If canine substitution is being considered, the possibility of converting the canine into an acceptable lateral-incisor substitute should be evaluated. Important characteristics include mesiodistal width, crown contour, facial convexity, cusp prominence, shade, and gingival margin position [9, 12, 14]. Planning must also include the first premolar, which will occupy the region normally associated with the canine and may contribute to lateral group function. Its intended final rotation, torque, vertical level, and occlusal role should be anticipated before active tooth movement begins [14, 20]. When the treatment objective is to preserve or create an implant site, coronal space alone is not sufficient. Adequate separation and angulation of the roots of the central incisor and canine are equally important [11, 14]. The alveolar ridge should also be evaluated because the site of congenital tooth absence may differ morphologically from areas where normal tooth development has occurred. Reduced ridge width and differences in facial alveolar contour have been reported [15, 17]. When three-dimensional assessment of bone and root relationships is clinically necessary, CBCT may assist in implant planning [17]. Chronological age should not be used as the sole determinant of suitability for implant placement. Natural teeth and the alveolar process can continue to change after adolescence, whereas an osseointegrated implant does not follow those changes [3, 11, 14, 19]. Assessment of growth completion is therefore particularly important when

implant-supported restoration of the anterior maxilla is planned. In unilateral agenesis, treatment planning should additionally include the contralateral lateral incisor. When that tooth is microdontic or peg-shaped, restorative correction may be required to achieve symmetry. In selected situations, extraction of the malformed contralateral lateral incisor followed by bilateral space closure has also been reported [12]. Because the final result depends on the interaction between orthodontic tooth positioning, gingival architecture, restorative requirements, and occlusal function, the intended end point should be defined before major orthodontic tooth movement is initiated [8, 11, 14, 19].

4. Treatment Modalities (Figure 1)

4.1. Orthodontic Space Closure

Orthodontic space closure redistributes the maxillary dentition so that the canine is moved into the missing lateral-incisor site and the posterior teeth are correspondingly mesialized. The first premolar then assumes the position normally occupied by the canine [1, 11, 14, 19, 20]. The aesthetic and functional success of this approach depends heavily on precise three-dimensional tooth positioning. Canine torque, angulation, and vertical position affect not only the visible crown but also the gingival contour and the relationship of the substituted tooth to the adjacent central incisor [14, 20]. Because canine morphology differs from that of a lateral incisor, orthodontic positioning is usually only one part of the final correction. The canine tends to be wider, more convex, more prominently cusped, and sometimes darker than the tooth it replaces. Depending on the initial morphology, finishing may therefore involve selective enamel reduction, composite addition, bleaching, or ceramic restoration [9, 12, 14, 20]. The first premolar must also be adapted to its new role. Control of rotation, torque, and vertical level may improve lateral function and reduce the risk of unwanted occlusal contacts [14, 20]. An important biological advantage of space closure is that the final anterior segment is composed of natural teeth supported by their own periodontal tissues. This eliminates the need to place an implant or another prosthetic unit directly within the missing lateral-incisor site [1, 14, 19]. The approach may be especially useful in younger patients because definitive tooth positioning can often be completed during adolescence rather than maintaining a prosthetic space until implant therapy becomes appropriate [5, 14, 19]. Nevertheless, the method should not be viewed as mechanically straightforward. Its success depends on the

initial dentofacial situation, the morphology of the canine, control of anchorage and tooth movement, and the quality of final restorative and occlusal finishing [9, 12, 14].

4.2. Space Opening or Maintenance

In the alternative treatment pathway, an existing edentulous space is preserved or orthodontically created so that the missing lateral incisor can subsequently be reconstructed [1, 11, 14, 19]. Preparation of the site requires more than achievement of an appropriate crown width. The roots of the adjacent central incisor and canine must be positioned so that sufficient interradicular space is available and their angulation is compatible with the intended restoration [11, 14, 17].

Implant-Supported Restorations

An implant-supported crown can replace the missing lateral incisor while leaving the adjacent teeth unprepared. Long-term survival of single-tooth implants is generally high [21]. However, survival of the implant itself does not fully describe treatment success in the anterior maxilla. The aesthetic result depends on the relationship between the prosthetic crown and the surrounding tissues, including interdental papillae, gingival margin level, soft-tissue colour, and the position of the crown relative to neighbouring natural teeth [4, 11, 19, 21]. The morphology and volume of the alveolar ridge may also restrict implant placement. Because the site of agenesis may present with limited bone dimensions, augmentation may be required before or during implant therapy in selected patients [15, 17].

Resin-Bonded Fixed Dental Prostheses

Resin-bonded fixed dental prostheses (RBFDPs) offer a more tissue-preserving restorative option than conventional fixed bridges because preparation of the abutment teeth can be minimal. They may be used as interim restorations or, under suitable conditions, as definitive treatment [2, 3, 21]. Their prognosis is influenced by case selection, prosthetic design, occlusal loading, and the quality of the adhesive procedure. Debonding, either partial or complete, remains one of the most commonly reported complications [2, 3, 21].

Conventional Fixed Dental Prostheses

Conventional tooth-supported bridges remain an available restorative option, but they require substantially greater preparation of the adjacent teeth than resin-bonded restorations [2]. This

biological cost is particularly relevant when the potential abutment teeth are intact and otherwise require no restorative intervention.

4.3. Alternative Therapeutic Approaches

Autotransplantation has been proposed as an alternative in selected patients when a suitable donor tooth and favourable anatomical conditions are available [15, 19]. In growing individuals, transitional implants and temporary restorations supported by skeletal anchorage devices have also been described. The evidence supporting these approaches is limited, however, because much of it comes from case reports and small clinical series rather than large comparative studies [16, 19]. Hybrid treatment concepts have likewise been reported. In some cases, the anterior space is closed by mesial movement of the canine while an implant site is created farther posteriorly in the arch [9, 10]. Such approaches may be useful in carefully selected situations, but the available case-based literature does not allow conclusions regarding superiority over conventional treatment strategies.

5. Comparison of Treatment Modalities

5.1. Aesthetic Outcomes

Aesthetic comparisons produce different rankings depending on the feature being assessed; consequently, the available evidence does not establish a uniform hierarchy of treatment options [1, 8, 9, 19, 21]. Studies based on objective photographic measurements have shown that canine substitution may perform favourably for selected variables related to tooth proportions, interproximal contacts, and black triangles, whereas RBFDPs may perform better for some variables concerning vertical crown position and gingival zenith [9]. The perception of treatment outcome also varies according to the observer. Patients and laypeople have often rated space closure favourably, while dental professionals may identify morphological or gingival discrepancies that are less relevant to non-professional observers [1, 8, 19]. The clinical interpretation of aesthetic evidence should therefore consider the individual components of the smile rather than assigning a single global ranking to each treatment method. Tooth width and contour, shade, papillary fill, gingival level, anterior symmetry, and the patient's own priorities may all influence treatment preference [8, 9, 19].

5.2. Periodontal and Soft-Tissue Outcomes

Orthodontic space closure has generally been associated with favourable periodontal findings in long-term observational studies [1, 14, 19]. Some earlier comparisons reported greater plaque accumulation and more gingival inflammation around prosthetic replacements than around natural teeth retained after space closure [1, 19]. More recent comparisons involving implant-supported crowns, however, have not consistently demonstrated poorer overall periodontal parameters in implant-treated patients [19]. The evidence therefore supports a favourable periodontal profile for space closure but does not justify assuming that a properly maintained implant restoration will necessarily lead to generalized periodontal deterioration. Local peri-implant tissue characteristics remain an important distinction. Differences in papillary fill, gingival margin level, and soft-tissue colour relative to neighbouring teeth have been described [4, 19, 21].

5.3. Functional and Occlusal Outcomes

Available comparative data indicate that an appropriately established group-function scheme can provide an acceptable functional result after canine substitution, and a consistent clinical benefit of canine-protected occlusion has not been demonstrated [1, 14, 19]. Long-term follow-up studies have also failed to show a consistent increase in temporomandibular disorders in patients treated with canine substitution compared with alternative strategies [1, 14, 19]. The first premolar can therefore participate in lateral group function when its position and occlusal contacts are properly controlled, without clear evidence from the analysed literature of an associated increase in periodontal damage [14, 19].

5.4. Long-Term Stability

Minor reopening of previously closed spaces may occur after orthodontic treatment. For this reason, prolonged retention, often using a fixed retainer, is commonly recommended [14, 21]. When the edentulous site is preserved, the space and adjacent root position must be maintained until the definitive restoration is completed [14]. Long-term considerations differ for implant-supported restorations because the implant behaves independently of subsequent positional changes of the adjacent natural dentition. This biological difference may become more relevant with increasing duration of follow-up [11, 14, 19].

5.5. Complications and Need for Retreatment

The burden of long-term maintenance differs according to treatment strategy. After space closure, additional treatment may include repair of bonded retainers and periodic modification, repair, or replacement of composite or other restorative materials used to alter canine and premolar morphology [14, 20, 21]. For RBFDPs, loss of adhesion may require rebonding or replacement of the restoration [2, 3, 21]. Implant-supported crowns may require management of prosthetic components as well as peri-implant soft or hard tissues. Importantly, aesthetic deterioration can occur even when the implant remains osseointegrated and clinically functional [4, 19, 21].

6. Factors Influencing Treatment Selection

The choice of treatment should emerge from the overall clinical picture rather than from any single diagnostic feature [1, 12, 14, 19]. Age and growth status strongly influence the sequence and duration of treatment. In a growing patient, space closure may allow completion of definitive orthodontic management during adolescence. By contrast, maintaining a future implant site usually requires prolonged preservation of the space and temporary replacement until growth has sufficiently stabilized [14, 19]. The existing malocclusion and distribution of teeth are equally important. Space closure has traditionally been considered particularly suitable when mesial movement of the maxillary dentition is compatible with correction of the occlusal relationship [14]. Skeletal anchorage has improved control of tooth movement and reduced some of the anchorage limitations that previously restricted mesialization, thereby increasing the range of situations in which space closure may be considered [14, 20, 21]. The intended position of the maxillary incisors and the soft-tissue profile should be evaluated regardless of the chosen approach. This consideration is especially relevant in patients with a tendency toward skeletal Class III relationships or a concave facial profile [5, 13]. Canine morphology may influence the feasibility and complexity of substitution. A broad, highly convex, or noticeably darker canine may require more extensive restorative modification to achieve acceptable integration within the anterior segment [9, 12, 14]. Where implant-supported replacement is planned, the importance of alveolar dimensions, interradicular space, soft-tissue phenotype, and gingival display increases [11, 14, 17, 19]. The morphology of the contralateral lateral incisor adds another layer of complexity in unilateral agenesis [12]. Beyond biological and occlusal considerations, patient expectations, treatment duration, financial implications, and the anticipated need for future maintenance or retreatment should beincorporated into shared decision-making[1,8,14,19,21].

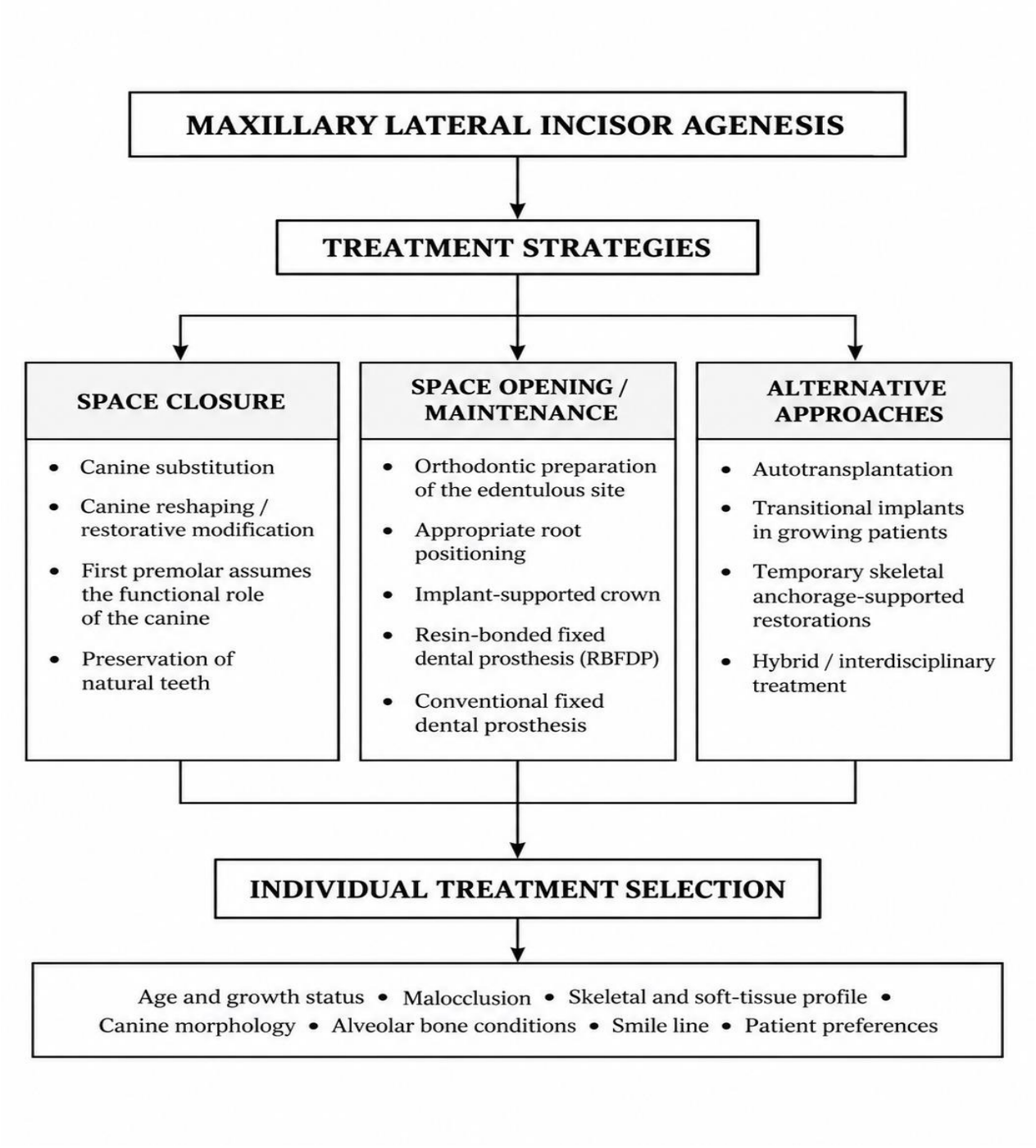


Figure. 1. Maxillary lateral incisor agenesis - treatment strategies.

7. Discussion

The reviewed literature indicates that treatment decisions in maxillary lateral incisor agenesis cannot be reduced to a universal protocol. Considerable variability exists among patients, and the evidence base itself is heterogeneous and often limited by retrospective designs and

relatively small study populations [1, 12, 19]. Consequently, therapeutic decisions should be interpreted within the context of the individual dentofacial characteristics of each patient rather than according to a single predetermined treatment concept. The available evidence is more useful for identifying clinical circumstances that may favour one strategy over another than for establishing an absolute hierarchy of treatment methods.

7.1. Skeletal Characteristics

Some investigations have identified shorter maxillary dimensions, lower SNA values, and less favourable sagittal jaw relationships in patients with bilateral agenesis [13]. These findings should be regarded as associations rather than evidence that agenesis itself produces a specific craniofacial pattern. Differences among published studies and the multifactorial nature of facial growth warrant caution when extrapolating these observations to individual patients [5, 13, 15]. In a comparative investigation of space opening and space closure, treatment-related changes were more pronounced in dental variables than in skeletal or soft-tissue measurements, with particularly relevant differences involving the position of the maxillary incisors [5]. This finding has a practical implication: the desired incisor position should be determined from the patient's skeletal and soft-tissue characteristics before the decision to open or close space is finalized. In particular, treatment mechanics should not be allowed to determine incisor position independently of the patient's sagittal relationships and facial profile. The orthodontic management of the available space should therefore remain subordinate to the overall dentofacial treatment objectives rather than becoming the principal determinant of the final anterior tooth position.

7.2. Aesthetics as a Multifactorial Outcome

Aesthetic outcome cannot be represented adequately by a single measurement. Different treatment strategies may perform differently depending on whether the variable under consideration is tooth proportion, interproximal contact, gingival position, crown colour, or another component of smile appearance [9]. Objective photographic analysis has demonstrated favourable findings for canine substitution in some parameters and for prosthetic replacement in others [9]. This variation makes it inappropriate to describe one method as consistently superior on aesthetic grounds alone. The perception of the result is also observer-dependent. Patients and laypeople may accept features that dental professionals regard as deviations from ideal morphology, and professional background has been shown to

influence aesthetic ratings [1, 8, 19]. After canine substitution, meticulous finishing becomes particularly important because canine contour, width, shade, and gingival level directly affect how successfully the substituted tooth integrates into the anterior segment [9, 14]. Therefore, assessment of treatment success should extend beyond tooth position alone and include the relationship between dental proportions, gingival architecture, symmetry, colour, and the appearance of the smile as a whole. The relative importance assigned to each of these variables may also differ from one patient to another, which further supports the need for individualized aesthetic planning.

7.3. Long-Term Aesthetic Stability of Implant-Supported Restorations

A distinction should be made between maintenance of osseointegration and maintenance of the original aesthetic relationship between an implant-supported crown and adjacent teeth. Natural dentition may continue to undergo subtle dentoalveolar changes during adulthood, whereas an implant remains fixed within the bone [11, 14, 19]. As a consequence, a crown that is well aligned at the time of placement may gradually become positioned more apically relative to the neighbouring teeth, producing relative infraocclusion. The extent of this change varies among patients and appears to be influenced by growth pattern and gingival display [11, 14]. Changes in peri-implant soft-tissue colour have also been documented in the lateral-incisor region [4]. These observations highlight why a favourable early implant result cannot be assumed to remain aesthetically unchanged over decades of follow-up. This distinction is particularly relevant in the anterior maxilla, where even relatively small changes in the vertical position of the crown or gingival margin may become visible during smiling. For this reason, assessment of implant treatment should include not only survival of the implant but also the stability of the relationship between the restoration, adjacent teeth, and surrounding soft tissues over time.

7.4. Alveolar Bone Conditions

The alveolar ridge in a site of congenital tooth absence may differ in both width and contour from alveolar bone associated with normally developed teeth [15]. Whether orthodontic movement of the canine can predictably improve the future implant site is less certain. The literature contains conflicting results, and methodological differences, particularly the use of dental casts versus three-dimensional imaging, make comparison difficult [17]. In one CBCT-based study, patients who underwent canine distalization did not show statistically significant

differences from patients without substantial distalization in the evaluated ridge dimensions, density, or buccal undercut [17]. Interpretation of these findings must take account of the study design. The investigation was cross-sectional, pretreatment CBCT data were unavailable, and the groups were small. For this reason, the evidence does not justify concluding that canine distalization has no effect on alveolar bone. Rather, current data do not support using distalization as a predictable means of avoiding bone augmentation before implant placement [17]. From a clinical perspective, this means that the future implant site should be evaluated individually rather than assuming that orthodontic tooth movement will necessarily provide adequate bone dimensions. The potential need for augmentation should therefore remain part of the initial interdisciplinary treatment discussion when space opening is selected.

7.5. Periodontal Considerations

The long-term periodontal profile of space closure is generally favourable [1, 14, 19]. Older comparative studies reported more plaque accumulation and less favourable gingival findings around some prosthetic replacements than around natural teeth following space closure [1, 19]. Not all contemporary comparisons between space closure and implant-supported rehabilitation have identified significant differences in overall periodontal health [19]. Thus, the most defensible interpretation is that space closure offers well-documented periodontal stability, while appropriately maintained implant-supported restorations may also achieve acceptable periodontal outcomes. The periodontal comparison between treatment strategies should therefore not be presented as an absolute opposition between healthy natural tissues and unhealthy prosthetic tissues. Rather, differences appear to concern the biological characteristics of the treated site, the type of reconstruction, maintenance requirements, and the quality of long-term oral hygiene and professional follow-up.

7.6. Functional Considerations

Concern regarding loss of conventional canine guidance has historically influenced treatment selection. Current comparative evidence, however, indicates that a balanced group-function arrangement may be functionally acceptable after canine substitution, and no consistent clinical superiority of canine guidance has been demonstrated [14, 19]. Likewise, available long-term observations do not show a consistent association between canine substitution and an increased prevalence of temporomandibular disorders [1, 14, 19]. Functional success

therefore appears to depend more on careful final tooth positioning, appropriate first-premolar relationships, and elimination of occlusal interference than on preservation of a specific disocclusion pattern [14, 20]. This observation shifts the clinical emphasis from reproducing a predetermined occlusal scheme to obtaining stable, interference-free functional contacts adapted to the final arrangement of the dentition.

7.7. Age and Growth

One potential advantage of space closure is the possibility of achieving a definitive dental result before growth has completely ceased [5, 14, 19]. This may spare younger patients from maintaining an edentulous space and wearing an interim prosthesis for several years before implant treatment becomes appropriate. However, young age alone does not constitute an indication for space closure. It must be interpreted together with the malocclusion, facial profile, canine morphology, and overall treatment objectives. Temporary implants and restorations supported by temporary anchorage devices have been proposed for growing patients, but the available evidence remains largely case-based and should therefore be interpreted cautiously [16, 19]. The duration of the transitional period is also clinically relevant, because a treatment plan involving future implant placement may require several years of space maintenance before definitive rehabilitation becomes possible. This prolonged sequence should be discussed with the patient and caregivers at the treatment-planning stage.

7.8. Resin-Bonded Fixed Dental Prostheses

RBFDPs are an important alternative when preservation of sound adjacent tooth structure is a priority [2, 3, 21]. Their long-term performance depends on design, bonding technique, occlusal loading, and patient selection. Debonding remains a recognized complication [2, 3, 21]. They should not, however, be regarded automatically as provisional restorations or as inferior to implants. In suitable clinical conditions, they may function as conservative definitive restorations. Their value is particularly relevant when clinicians wish to minimize irreversible intervention in adjacent teeth while maintaining the possibility of future modification of the treatment plan.

7.9. Retention and Long-Term Maintenance

Following space closure, small spaces may reopen, making long-term retention an important component of management [14, 21]. Fixed retainers reduce this risk but may themselves

require repair. Long-term follow-up data indicate that retainer debonding can account for additional treatment visits [21]. Patients treated by space opening also require ongoing supervision before and after final prosthetic reconstruction. Therefore, neither principal strategy is entirely free from long-term maintenance requirements. This aspect is important when counselling patients, because the end of active orthodontic treatment does not necessarily represent the end of treatment-related care. Long-term success depends partly on continued observation and appropriate management of both retention and restorative components.

7.10. Cost and Overall Treatment Burden

Economic evidence relating specifically to maxillary lateral incisor agenesis remains limited. In the available long-term cost analysis, the additional orthodontic treatment associated with space closure did not result in greater overall expenditure. When direct and indirect costs were assessed from a societal perspective, the implant-treated group generated higher total costs over the study period [21]. These findings should be interpreted within the context in which the study was conducted. Healthcare funding, subsidies, taxation, travel requirements, and other local economic factors may substantially influence the transferability of cost estimates. The broader implication is that economic assessment should include not only the initial procedure but also long-term maintenance, repairs, additional interventions, and productivity losses. In clinical practice, the concept of treatment burden may therefore be more informative than comparison of the initial price of individual procedures alone. A treatment that appears less demanding at the time of completion may generate additional biological, financial, and logistical requirements during subsequent years.

7.11. Preferred Treatment Strategy

When both principal treatment pathways are clinically possible, the literature suggests that space closure can provide a favourable overall balance of periodontal, aesthetic, and functional outcomes [1, 19, 21]. The use of natural teeth and avoidance of an implant within the anterior aesthetic zone are important advantages. Nevertheless, space closure should not be selected automatically. Incisor position, facial profile, malocclusion, canine morphology, gingival display, and the patient's aesthetic expectations may favour preservation or opening of the space [9, 12, 14]. Implant-supported reconstruction remains a reasonable option in appropriately selected adults when alveolar dimensions, soft tissues, root relationships, and

interdisciplinary treatment objectives are favourable [11, 17, 19]. The available evidence therefore supports individualized balancing of benefits, limitations, and future treatment burden rather than a fixed preference for one modality in every patient. Importantly, the most appropriate treatment may not necessarily be the method that produces the most ideal result according to a single professional criterion, but rather the option that provides the most acceptable combination of aesthetics, function, biological stability, treatment duration, maintenance requirements, and patient expectations.

7.12. Limitations of the Available Evidence

Interpretation of the literature is limited by the predominance of observational and retrospective investigations and by relatively small samples in many studies [1, 9, 12, 17, 21]. Outcome measures are also inconsistent. Aesthetic studies differ in the parameters they assess, the methods used to record them, and the professional background of the evaluators [8, 9]. Studies of alveolar morphology likewise vary in imaging technique and measurement methodology [15, 17]. The duration of follow-up is particularly important in implant research because some aesthetic changes may not become apparent until years after the initial restoration [4, 14, 19]. Future research would benefit from prospective comparative designs, larger study populations, standardized outcome measures, and longer observation. Patient-reported outcomes, quality of life, maintenance burden, and the number of subsequent interventions should be assessed alongside conventional clinical measures. Greater standardization would also facilitate more reliable comparison between treatment strategies and allow future systematic reviews to draw stronger conclusions. Until such evidence becomes available, clinical recommendations should remain appropriately cautious and should acknowledge the limitations of the current literature.

8. Conclusions

Management of maxillary lateral incisor agenesis requires individualized diagnosis and treatment planning based on the complete dentofacial situation.

Treatment generally follows one of two pathways: orthodontic redistribution of the dentition to eliminate the missing-tooth space or preservation and preparation of the site for later restorative replacement.

Orthodontic space closure can provide favourable long-term periodontal, aesthetic, and functional outcomes when case selection, tooth positioning, and restorative

finishing are carefully controlled. Successful canine substitution frequently requires modification of canine form and shade together with appropriate repositioning of the first premolar.

In growing patients, space closure may permit definitive dental treatment before growth completion and may avoid prolonged maintenance of a prosthetic space.

Implant-supported crowns provide a predictable restorative solution in appropriately selected patients, but continued implant survival should not be equated with permanent stability of the aesthetic result.

Long-term aesthetic concerns after implant replacement may include relative infraocclusion, changes in gingival levels, altered papillary fill, and peri-implant soft-tissue colour differences.

Available evidence supports group function as an acceptable occlusal scheme following canine substitution and does not establish a consistent functional advantage for canine guidance.

RBFDPs offer a conservative alternative to implant-supported crowns and may serve either interim or definitive purposes when appropriately indicated.

Treatment selection should incorporate future maintenance, retention, potential complications, need for additional procedures, and the biological and financial burden of care, rather than focusing exclusively on the immediate post-treatment appearance.

The available evidence favours case-specific treatment selection rather than a universal hierarchy of therapeutic approaches. Final decisions should integrate individual clinical conditions, the best available evidence, and informed patient preferences.

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