Canine substitution using clear aligners—a case report and literature review

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This case report describes a 16-year-old male patient who presented with bilateral peg-shaped lateral incisors, Class II Division 1 incisors and a Class II buccal occlusion. The patient chose to remove the peg-shaped lateral incisors and have the anterior spaces closed using clear aligners. The treatment involved 11 mm of space closure gained by retracting the central incisors and mesialisation of the posterior teeth. A satisfactory aligner result was achieved after 20 months. Following space closure, canine enameloplasty was performed using the central incisors as a reference. The colour of the canines will be improved through whitening after the completion of orthodontic treatment. The present study describes the successful closure of an 11 mm space using clear aligners to allow for canine substitution, thereby demonstrating the effectiveness of aligners in complex cases requiring large space closure and precise root movement control. It provides an insight into an alternative approach for managing similar cases. The present report highlights the importance of individualised treatment planning, optimal design of the aligner attachments, good control of root movements, and the regional acceleratory phenomenon (RAP) in the success of canine substitution. The treatment strategy could serve as a useful reference for practitioners dealing with similar orthodontic challenges.
(Aust Orthod J 2025; 41: 130 - 139. DOI: 10.2478/aoj-2025-0009)

Received for publication: December, 2024
Accepted: March, 2025.

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Introduction

A peg-shaped tooth is identified when the incisal mesiodistal crown width is narrower than the cervical crown width.[1] It most commonly affects one or both maxillary permanent lateral incisors, potentially causing aesthetic concerns for the affected patients. Peg-shaped teeth are associated with the expression of a specific genetic mechanism.[2] There is a continuous distribution of tooth sizes, with hypodontia and supernumerary teeth on the two ends of the continuum.[3] The overall prevalence of peg-shaped lateral incisors is approximately 1.8%, but varies according to ethnicity, the environment and gender.[4]

Treatment options for peg-shaped maxillary lateral incisors usually include either accepting the shape of the lateral incisors, prosthodontically building up the diminutive teeth, or orthodontically closing the spaces following extraction of the dysmorphic teeth (i.e. canine substitution).[5] The treatment decision depends on multiple clinical factors, which are associated with the patient's preference, age, facial profile, lip line, the size and shape of the canines, the amount of spacing or crowding present, tooth size relationship, and the type of malocclusion.[6] The ideal treatment plan should fulfil the patient's aesthetic and functional demands.

Clear aligners have become increasingly popular. They are an aesthetic, comfortable, and a hygienic alternative to traditional fixed appliances.[7–9] Clear aligners have been developed and refined over recent decades to achieve desirable tooth movements. However, treating extraction cases using aligners, including canine substitution, remains challenging. Aligners differ from conventional orthodontic braces in that tooth movement is driven by the distortion of the aligner upon insertion. The amount of tooth movement is constrained in all dimensions at a rate dictated by the aligner. Maintaining an intimate fit between the aligner and tooth is essential to deliver appropriate force levels and vectors. A poor fit of the aligners leads to non-tracking of the teeth.

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Figure 1. Pre-treatment intra- and extra-oral images and intraoral scans.

The efficacy of different types of tooth movement using clear aligners varies. For example, the pure tipping movement, simply involving only the crown, is the most predictable, whilst root movements are much less accurate.[10] Treating canine substitution cases with aligners can be challenging because the outcome requires extensive movement of the large canine roots to replace the missing upper lateral incisors, followed by the mesialisation of all the premolars and molars to close the remaining extraction spaces.

Diagnosis and aetiology

The present case report describes a 16-year-old male who was concerned about his peg-shaped maxillary lateral incisors and an increased overjet. He mentioned being able to fit his tongue between his upper and lower front teeth and reported having a lisp, which he attributed to the malocclusion. Additionally, he experienced crepitus in the left temporomandibular joint, although it was asymptomatic. Apart from mild hay fever, the patient was otherwise healthy and attended regular dental examinations with a private dentist.

When smiling, the patient displayed a symmetrical, tapering face with a normal upper lip line (Figure 1). His profile was convex, suggesting a skeletal Class II pattern. The chin-throat angle was well-defined, the nasolabial angle was slightly obtuse, and both lips were aligned with the aesthetic line (E-line).

Intraorally, the patient exhibited fair oral hygiene, good periodontal health, a normal gingival phenotype, and no carious lesions (Figure 1). All permanent teeth were present, including four unerupted third molars. Both upper and lower arches were relatively well-aligned, but with several minor tooth rotations. The patient had a bilateral Class II molar relationship, a 5 mm overjet, and a 40% overbite. The peg-shaped upper lateral incisors caused a clinically significant Bolton tooth-size discrepancy between the upper and lower arches, noted by a 5 mm maxillary deficiency which suggested that a proper overjet and overbite could not be achieved as a result of the current tooth sizes.[11] Mild spacing was observed on the mesial and distal aspects of both upper diminutive lateral incisors, along with spacing between the lower incisors. Mild wear was noted on the incisal edges. The upper midline deviated 0.5 mm to the left of the facial midline, while the lower midline aligned with the facial midline. The curve of Spee was accentuated.

The pretreatment panoramic radiographs revealed no bony abnormalities, and the condyles appeared normal and symmetrical. The lateral cephalometric radiograph indicated that the patient was at cervical vertebral maturation stage 5, which suggested minimal remaining growth potential (Figure 2). A cephalometric analysis (Tables I and II) showed an increased the ANB angle. Both the SNA and SNB angles were within the normal range, indicating that the skeletal Class II pattern resulted from a combination of a mildly protrusive maxilla and a slightly retrusive and short mandible. The upper incisors were slightly retroclined, and the lower incisors were slightly proclined, but both were within one standard deviation of the normal range.

Figure 2. Pre-treatment lateral cephalogram.

Treatment objectives

The treatment objectives were to reduce the overjet and overbite, address the peg-shaped maxillary lateral incisors, and enhance the dental aesthetics.

Treatment options

Three treatment options were presented to the patient and his parents, and option 3 was chosen.

Option 1: No treatment, since the teeth were relatively well-aligned. This was dismissed due to the patient's aesthetic concerns.

Option 2: Orthodontic treatment combined with prosthodontic build-up of the peg-shaped lateral incisors. While this option could provide pleasing dental aesthetics, it would require life-long maintenance of direct or indirect restorations on both lateral incisors. Given the patient's age, the ongoing maintenance could become a future burden. Additionally, this approach would not address the patient's primary concerns of an increased overjet.

Option 3: Canine substitution, which involved extracting the peg-shaped lateral incisors and orthodontically closing the spaces. The canines in this treatment plan would substitute for the lateral incisors, and the first premolars would substitute for the canines. This option eliminated the need for life-long maintenance of prosthetic restorations and offered better periodontal conditions compared to patients with composite crown build-ups or indirect prostheses.[12] Since the patient had passed his growth spurt (CVS 5), growth modification was not feasible to reduce the overjet, making extractions in the maxillary arch necessary. Extracting the peg-shaped lateral incisors was deemed more reasonable and suitable than extracting other teeth. Although the

Table I. Pre-treatment cephalometric values

		Value	Norm	Standard deviation
SNA	(dg)	83.5	80.9	4.1
SNB	(dg)	77.3	78.3	3.9
ANB	(dg)	6.2	2.5	2.4
Wits	(mm)	5.2	0.9	3.6
S-N	(mm)	64.2	70.3	3
NAP	(dg)	8.6	1.6	6.1
Go-Me	(mm)	67.2	72.6	4.2
ANS-PNS	(mm)	52.8	52.5	2.8
SN-FH	(dg)	10.4	10.7	2.3
FMPA	(dg)	23.3	23	5.1
MMPA	(dg)	29.8	26.8	5.7
Y-axis	(dg)	68.1	56.4	3.5
Facial axis	(dg)	89.9	88.9	4.6
Sn-Mx pl	(dg)	3.9	6.8	2.9
Sn-Mn pl	(dg)	30.7	33.6	6.1
Ba-S-N	(dg)	134.4	130.1	5.5
Na-Me	(mm)	106.3	118.2	6.8
Na-ANS	(mm)	47.2	53.4	2.6
ANS-Me	(mm)	59.1	65.9	5.5
LAFH%	(%)	56.8	55.8	—
S-Go	(mm)	67.5	76.8	4.8
UIA	(dg)	104.9	110	8.2
LIA	(dg)	96	91.7	7.7
Mn 1-APo	(dg)	24.7	24.6	5.1
Mn 1-APo	(mm)	0.1	1.2	2.7
Interincisor	(dg)	129.2	131.3	11

Table II. Post-treatment cephalometric values

		Value	Norm	Standard deviation
SNA	(dg)	84.1	82	4.6
SNB	(dg)	79.3	79.7	4.5
ANB	(dg)	4.7	2	2.9
Wits	(mm)	6.6	1.4	3.8
S-N	(mm)	77.2	71.5	2.9
NAP	(dg)	5.1	2	7.6
Go-Me	(mm)	79.7	75.9	4
ANS-PNS	(mm)	62.8	53.8	3.3
SN-FH	(dg)	10.7	10.2	2.8
FMPA	(dg)	18.9	21.6	5.7
MMPA	(dg)	26.8	22.7	7.6
Y-axis	(dg)	65.9	55.8	3.8
Facial axis	(dg)	92.3	87.5	4.8
Sn-Mx pl	(dg)	3	6.1	2.4
Sn-Mn pl	(dg)	26	31.8	6.8
Ba-S-N	(dg)	129.2	129.4	5.4
Na-Me	(mm)	126.9	120.9	6.9
Na-ANS	(mm)	56.1	53.6	2.1
ANS-Me	(mm)	70.9	67.4	6.3
LAFH%	(%)	56.6	55.7	—
S-Go	(mm)	86.0	80.5	4
UIA	(dg)	100.8	113.5	6.6
LIA	(dg)	95.4	90.6	9.1
Mn 1-APo	(dg)	23.9	24.2	5.5
Mn 1-APo	(mm)	-0.6	1.1	2.5
Interincisor	(dg)	137.2	130.8	11.4

maxillary canines were larger than ideal to substitute for the lateral incisors, adequate aesthetics could be achieved with proper enameloplasty and control of palatal root torque during treatment.[12] The patient accepted the slight colour difference between the canines and central incisors, understanding it might affect the final aesthetic outcome, and chose to proceed with this plan after considering the advantages and disadvantages of each option.

Clear aligners were selected as the treatment modality due to the relatively well-aligned maxillary and mandibular arches and the patient's preference.

Treatment progress

The patient's teeth were scanned using an intraoral scanner and sent to Angelalign™ for treatment planning. The instructions included digitally removing the peg-shaped upper lateral incisors (Figure 3) and closing the spaces by retracting the central incisors and mesialising the canines and posterior teeth. Phantom interproximal reduction was prescribed between the central incisors and canines to ensure complete space closure. Large vertical rectangular attachments were prescribed on the canines to provide root control during space closure (Figure 3).

The peg-shaped lateral incisors were extracted one week before the aligners were inserted. The appliances were worn for at least 22 hr per day, with each aligner used for 10 days. By the end of the initial treatment phase, the extraction spaces were closed through the retraction of the central incisors and mesialisation of the posterior teeth. The anterior teeth were in an edge-to-edge relationship (Figure 4), but a mild bilateral buccal open bite had developed. This issue arose due to the difficulty of moving the entire upper posterior dentition forward despite attempts to use the overbite and curve of Spee for anterior incisal anchorage during the process.

Additionally, mesial tipping of the upper molars and palatal crown tipping of the upper incisors were observed because the force was applied above the centre of resistance for both the incisors and the molars. During the refinement phase, palatal root torque was prescribed for the incisors and canines with over-correction in the ClinCheck plan to address these anticipated issues.[10] Night wear of Class III elastics was utilised to improve the overjet and reinforce intermaxillary anchorage. Enameloplasty of the canines was performed progressively at each review appointment. Large, horizontal, rectangular attachments replaced those already fixed to the premolars, molars, and upper canines to enhance vertical control (Figure 5). The new attachments facilitated the extrusion of the canines to allow for further enameloplasty, the extrusion of lower posterior teeth to flatten the curve of Spee, and buccal root torque of the upper posterior teeth to improve interdigitation. The final enameloplasty of the canines was completed at the debond appointment.

Fixed upper and lower retainers were bonded to the lingual surfaces of the canines and incisors.

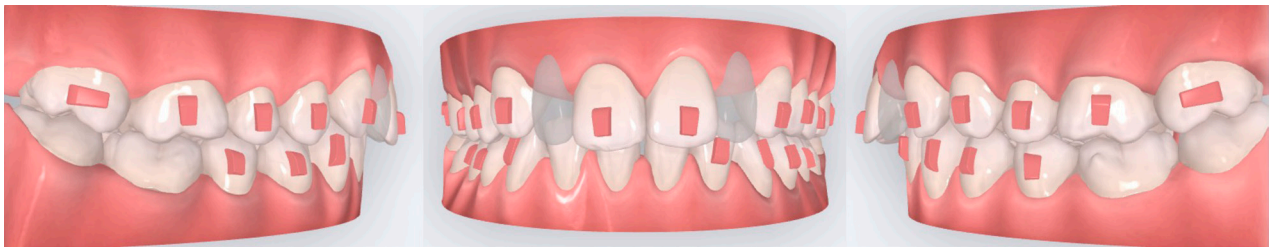

Figure 3. Digital set-up showing the digital removal of the peg-shaped upper lateral incisors and the vertical attachments.

Additionally, vacuum-formed retainers were prescribed as a backup in case the fixed retainers failed.

Treatment results

The post-treatment photographs show a more mature patient with a balanced profile. The smile is pleasing, and the smile arc follows the lower lip line (Figures 6 and 7). The shape of the modified canines blends well with the rest of the dentition, although their colour appears slightly darker than the central incisors. Therefore, selective whitening is planned. Intraorally, a 1mm overjet and a 20% overbite were achieved, and both upper and lower midlines were centred. Good posterior buccal interdigitation was obtained with a solid Class II molar relationship bilaterally. The maxillary central incisors and canines are upright due to the under-expression of palatal torque.

Discussion

Clinical management of the peg-shaped maxillary lateral incisors involves considering factors related to the patient's age, facial profile, lip line, size and shape of the canines, the amount of spacing or crowding, tooth size relationship, and type of malocclusion.[6] In the present case, the patient with peg-shaped maxillary lateral incisors was successfully treated by extracting the hypoplastic maxillary teeth and pursuing canine substitution. This approach avoided the lifelong burden of maintaining prosthodontic restorations on the peg-shaped lateral incisors, thereby making it a more suitable option for a 16-year-old patient.

Peg-shaped lateral incisors are often considered a subset of diminutive lateral incisors. Diminutive lateral incisors generally refer to those teeth that are smaller in size but maintain a normal tooth shape. In contrast, peg-shaped lateral incisors have a conical shape, which can significantly impact aesthetics, making extraction and canine substitution treatment more likely to be indicated.

Ideal candidates for canine substitution are typically those with a Class II malocclusion and without crowding in the mandibular arch or those with a Class I malocclusion who require lower extractions to relieve crowding.[6] The patient in this case report

Figure 4. Intra- and extra-oral images and intraoral scans after the initial set of aligners.

Figure 5. Digital set-up showing the horizontal attachments.

presented with a Class II malocclusion and minor spacing in the lower arch, making him a suitable candidate for canine substitution. The patient's facial profile also influenced the treatment decision. Extractions may not be ideal for individuals with moderate to severely retrusive profiles, as soft tissue support could be affected. However, the current patient had a pleasant profile despite a slightly retrognathic mandible before treatment, and retraction of the upper incisors did not significantly affect the profile. Additionally, the patient did not have a high smile line, and so gingival aesthetics were less of a concern compared to those patients with a high smile line.[13]

A diagnostic set-up is recommended during treatment planning to assess the final occlusion and potential compromises due to a Bolton's tooth-size discrepancy. Canine substitution often leads to an anterior tooth size discrepancy identified as a maxillary excess. Therefore, anteroposterior reduction of the canine width is frequently necessary to achieve optimal overjet, overbite, and aesthetics.[6] In the present case, an acceptable overjet and overbite were achieved with minimal anteroposterior reduction of the canines, likely because of the large size of the lower anterior teeth.

Canines typically have wider crowns and,[14] in this case, enameloplasty was gradually carried out at each review to minimise sensitivity, particularly at the pointed cuspal tips and the canine labial surface. Additionally, canines are often darker than central incisors and so individual tooth bleaching might be recommended at the end of treatment if aesthetics are a concern. Ideally, canines used for substitution should be narrow mesiodistally and labiopalatally, have a flat labial surface, and match the colour of the central incisors.[6]

Adequate palatal root torque is necessary for substituted canines to conceal root prominence. Ideally, the canines should be extruded, and the premolars intruded to achieve gingival margin heights that resemble those of natural lateral incisors and canines. The gingival margins of the central incisors and canines should be at the same level and 1mm higher than those of the lateral incisors.[15] Alternatively, a gingivectomy might be needed at the end of treatment to enhance aesthetics.

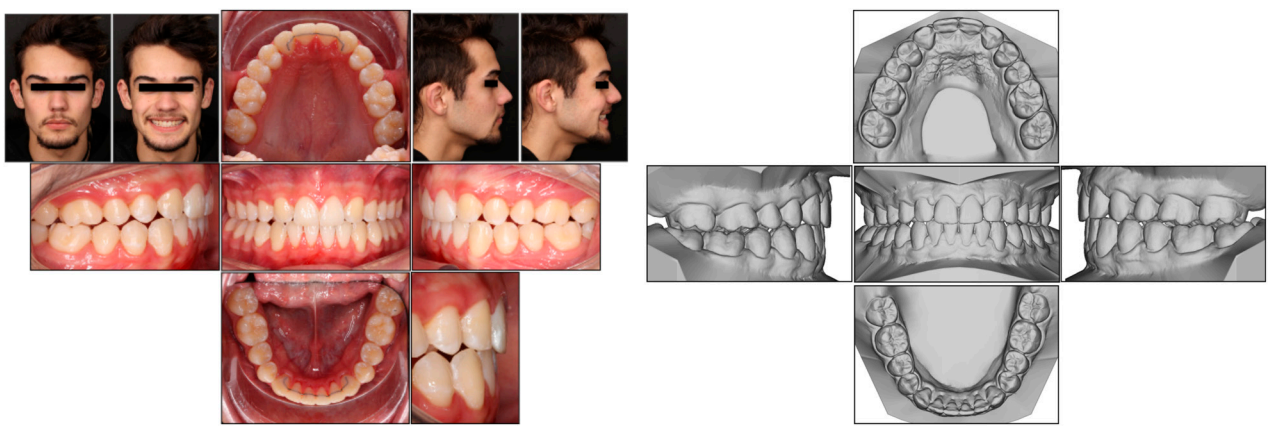

Figure 6. Intra- and extra-oral photos and intraoral scans at debond.

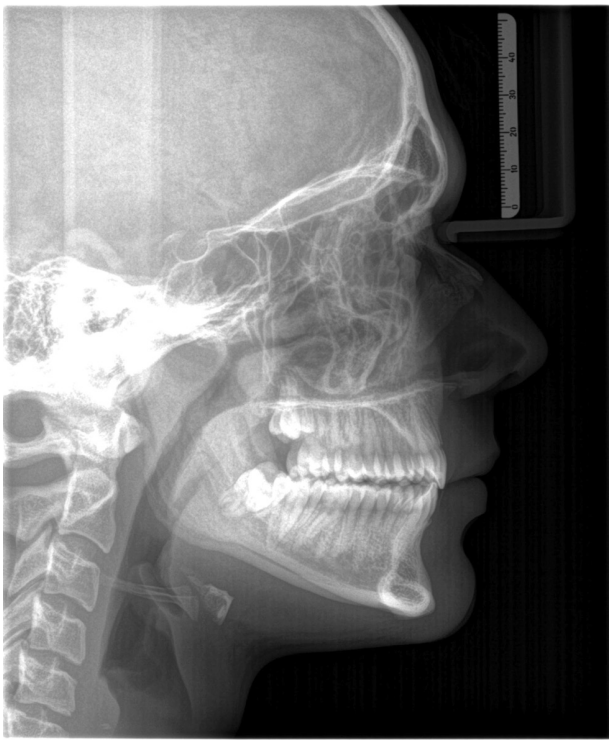

Figure 7. Post-treatment lateral cephalogram.

In hindsight, incorporating overcorrection into the initial aligner plan could have improved treatment efficiency and outcomes. The predictability of aligners varies based on the specific tooth and type of movement, with incisor torque expression averaging around 35%.[10] Consequently, significant overcorrection is often needed to achieve the desired torque for the anterior teeth. While there is no current evidence regarding the predictability of en-masse mesialisation of the posterior teeth, the high anchorage demands due to the number of involved teeth pose a challenge for aligners without auxiliary appliance assistance. Insufficient overcorrection can compromise the final result, which necessitates refinements. However, the effectiveness of improvements diminishes with each subsequent refinement, and after three refinements, further enhancements are unlikely and may even cause side effects.[16] An increased number of refinements also significantly prolongs treatment duration and so, exploring alternative treatment options is worthy of consideration.[16]

Modern clear aligner technologies now use computer-aided design and manufacturing (CAD/CAM), stereolithography, and three-dimensional tooth movement simulation software to streamline treatment planning.[17] These technologies enabled more precise tooth movements through computerised interactive planning, appliance design, the incorporation of bonded resin attachments, and altered aligner geometries (such as power ridges, pressure points, elastic cut-outs, and bite ramps).[17] Power ridges are intended to aid in delivering palatal root torque to the incisors. However, studies have found no significant difference in the predictability of incisor torque expression with or without power ridges.[18–20] Some clinicians use temporary anchorage devices to apply both intrusive and retraction forces to achieve effective incisor torque control.[21]

Optimised attachments from Invisalign® were designed to enhance biomechanical force delivery and improve the efficacy of tooth movements. However, a recent retrospective study found no difference in the effectiveness of rotational and extrusive movements between optimised and conventional attachments.[22] An additional study indicated that optimised attachments might produce either favourable or undesirable effects, depending on the specific movements or the teeth to which they are applied.[18]

Extrusion is the least predictable movement, with an overall accuracy of 29.6%.[23] However, the extrusion of maxillary canines is relatively more predictable compared to other anterior teeth, with an accuracy of 49.9%.[23] In this case, large horizontal attachments were used during the refinement stage to optimise buccal extrusion and enhance interdigitation. Proper design and the accurate prescription of attachments are crucial for controlling root movement during space closure and achieving optimal root parallelism and intercuspation post-treatment. Attachments improve aligner retention by increasing the surface area of the teeth, allowing for more complex force systems, and enhancing the predictability of complicated tooth movements. The vertical attachments used initially assisted with root uprighting of the canines during space closure,[18] while the horizontal attachments improved the curve of Spee, posterior intercuspation, and canine extrusion towards the finishing stage of treatment.[24] Previous studies have shown that vertical rectangular attachments reduce molar crown tipping during distalisation.[25] It is reasonable to assume that they would have a similar effect during the mesial movement of the molars in the present case. Wider attachments theoretically have a narrower critical

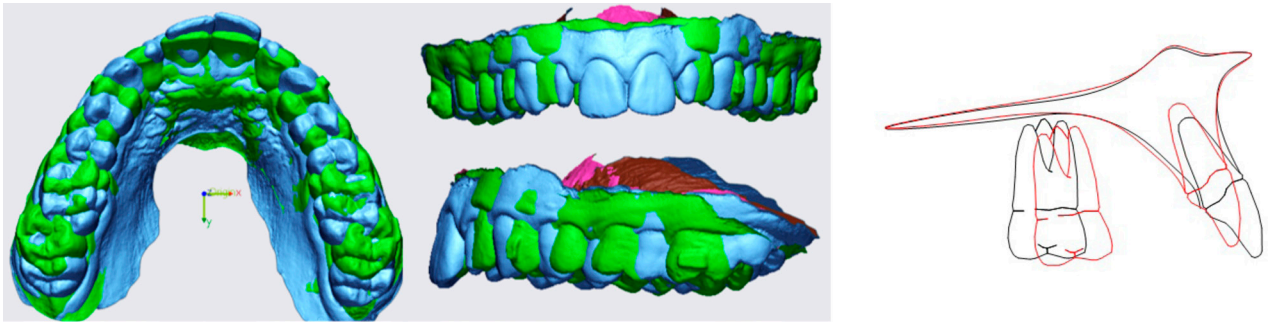

Figure 8. Superimposition of the pre- and post-treatment intraoral scans using the best-fit method and lateral cephalogram superimposed on the palatal plane (ANS-PNS), registered at ANS.

angle during tipping movements, thereby allowing the critical angle to be reached earlier and the upright motion to begin sooner, potentially reducing tooth tipping. However, to the best of current knowledge, no studies have yet explored how the size of rectangular attachments affects the predictability of tooth movement.

In the present case, canine substitution was accomplished using aligners by retracting the central incisors, mesialising the posterior teeth, and narrowing the maxillary arch, as confirmed by the superimposition of the pre- and post-treatment intraoral scans and lateral cephalogram (Figure 8). Previous studies have shown that an expansion of more than 2.5 mm in intercanine width or 5 mm in intermolar width is required to achieve a 2 mm increase in arch perimeter.[26] It could be assumed that the reverse is true, in which constriction of the maxillary arch assisted with space closure during the treatment process.

Additionally, the regional acceleratory phenomenon (RAP) may have contributed to successful tooth movements.[27] In the present case, the peg-shaped lateral incisors were extracted one week prior to the insertion of the aligners thereby potentially allowing RAP to occur. RAP occurs after the extraction of teeth and by stimulating the repair process in the recruitment and activation of precursor cells essential for wound healing.[27] It accelerates the hard and soft tissue healing around the extraction site and aids with tooth movement, facilitating the clinical efficiency of space closure. However, RAP typically lasts only a few months following an initial injury, and so space closure of older extraction sites may be more challenging.[28]

Good patient compliance is essential for the success of clear aligner treatment.[29] Patients are generally advised to wear their aligners for 22 hr a day to achieve the desired results. In the present case, the patient followed a 10-day replacement regimen. The recommended frequency for changing aligners varies based on factors such as patient compliance, the prescribed tooth movements, and the overall complexity of the treatment.[30,31] Research has also shown that a 10-day change regimen can be as effective as a 14-day regimen when tooth movement efficacy is considered.[32] Further studies are needed to determine the optimal wearing protocol for each patient.

In the present case, the canines were slightly darker than the incisors. Tooth whitening may be performed either during or after orthodontic treatment, depending on patient preferences. Whitening during clear aligner treatment can be advantageous, as the aligners can function as whitening trays, potentially reducing costs for the patient. This method has been shown to produce comparable whitening results to conventional bleaching trays, even with attachments in place.[33] The use of whitening agents, such as carbamide peroxide, can reduce the hardness and increase the surface roughness of clear aligner material. However, this is typically not a major issue, as aligners are usually replaced every 1-2 weeks.[34] Additionally, vacuum-formed retainers are sometimes used as whitening trays after orthodontic treatment, although their long-term performance may be affected by decreased tensile strength and increased hardness and internal roughness.[35]

Conclusion

Canine substitution via the retraction of central incisors and mesialisation of the posterior teeth

was successfully completed using clear aligners. It provided an insight into an alternative approach for managing similar cases. A number of clinical factors should be considered before deciding on the extraction of peg-shaped lateral incisors and orthodontic space closure, including the patient's age, facial profile, lip line, the size and shape of the canines, the amount of spacing or crowding present, tooth size relationship, and the type of malocclusion. The appropriate selection of cases, effective treatment planning, well-designed aligner attachments, adequate enameloplasty on the substituted canines, and good patient compliance directed at wearing the aligners contributed to the successful large space closure and the satisfactory treatment outcome.

Conflict of interest

The authors declare that there is no conflict of interest.

Authors contribution

YL contributed to the clinical treatment, data collection and analysis, and drafting the manuscript; LM contributed to the clinical supervision, data collection and analysis, and revising the manuscript.

Data availability

Questionnaire is available on request.

Funding statement

This research did not receive any funding.

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