Canine substitution of congenitally missing maxillary lateral incisors in Class I and Class III malocclusions by using skeletal anchorage

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Introduction: This prospective cohort study aimed to evaluate canine substitution supported by skeletal anchorage as a viable treatment protocol for patients with maxillary lateral incisor agenesis (MLIA) and skeletal Class I or Class III. **Methods:** Patients (n = 30) who met the following criteria were recruited: (1) bilateral MLIA or unilateral MLIA with a riziform contralateral incisor with a planned extraction; (2) skeletal Class I or Class III; and (3) dentoalveolar discrepancy in the mandible <5 mm. The archwire sequence routine was administered, combined with a rapid palatal expander, temporary intraoral skeletal anchorage device, and intermaxillary traction with Class III elastics. The results of the cephalometric analyses, peer assessment rating indexes, and the patient's smile self-evaluation using the visual analog scale were compared between initial and final treatments. **Results:** This study indicated that closing the space in patients with Class I or Class III malocclusion by using temporary intraoral skeletal anchorage devices in the mandible, along with Class III elastics, yielded satisfactory outcomes. Proper occlusion was established by mesialization of the maxillary teeth and correction of the intermaxillary discrepancy, thereby yielding beneficial and significant cephalometric changes after the treatment. The soft tissue profile was maintained when it was harmonious before the treatment and improved posttreatment in patients in whom the profile was initially inharmonious. All occlusions improved, as evidenced by the peer assessment rating index. Smile esthetics were also enhanced after orthodontic treatment for all patients. **Conclusions:** Canine substitution may be safely offered to patients with Class I and Class III skeletal pattern and MLIA. (Am J Orthod Dentofacial Orthop 2019;156:512-21)

Tooth agenesis affects 20% of the world's population, and maxillary lateral incisor agenesis (MLIA) is one of the most frequent subtypes. The prevalence of MLIA varies from 1.15% to 5% in different populations.[1-3] It is characterized by a lack of formation of the deciduous or the permanent lateral incisors because of impaired odontogenesis. The latter process is a complex mechanism regulated by sequential and reciprocal epithelial-mesenchymal interactions, controlled by activators and inhibitors involved in several pathways. Disturbances in these signaling cascades can lead to abnormalities in odontogenesis and alterations in the standard number of teeth. Alves-Ferreira[1] reported the first evidence of the involvement of sprouty genes in MLIA susceptibility; however, it is not uncommon for MLIA to be associated with multiple dentoalveolar and skeletal malformations.

The aforementioned malocclusion may develop in a unilateral MLIA (UMLIA) or bilateral MLIA (BMLIA) form. In UMLIA, the left and right sides are both affected, with no significant differences between them. The prevalence of microdontic contralateral lateral incisors is higher in patients with UMLIA than in patients with no MLIA.[4] Microdontia of the contralateral maxillary incisor occurs in approximately 38.8%-52.4% of patients.[5,6]

Multiple treatment options are available for congenitally missing lateral incisors such as canine substitution, single-tooth implant, and tooth-supported restorations.

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In 2011, in an article under the Point/Counterpoint series published in the *American Journal of Orthodontics and Dentofacial Orthopedics*, Zachrisson et al[7] (ie, proponents of canine substitution) and Kokich et al[8] (ie, proponents of restorative replacement) meticulously covered the topic of treatment options for congenitally missing maxillary lateral incisors. The authors showed the advantages and disadvantages, alongside the indications and contraindications, of each treatment option. They agreed on 2 points: (1) the use of an interdisciplinary treatment approach is beneficial to obtain the most predictable outcome and (2) the candidate for canine substitution should ideally have a harmonious profile, a Class II dental relationship, and no crowding in the mandibular arch.[7,8]

Continuing the debate on the pros and cons of canine substitution, Schneider et al[9] in 2016 proved that orthodontists and dentists rank implants and space closure as equally pleasing, but laypersons prefer canine substitution. Silveira et al[10] also reported in their 2016 systematic review worse scores for the periodontal indexes in patients with tooth-supported dental prostheses than in patients with orthodontic space closure. The second option was evaluated to be esthetically better than prosthetic replacements. Furthermore, the presence or absence of Class I malocclusion of the canines showed no relationship with occlusal function or with signs and symptoms of temporomandibular disorder.[10]

The dentoalveolar and skeletal widths in patients with UMLIA and BMLIA as evaluated by Buyuk et al[6] and the sagittal dimension as investigated by Bassiouny et al[2] favored implant replacement as the appropriate treatment option. The 2 studies mentioned earlier confirmed significantly smaller values for the maxillary intercanine width and the maxillary intercanine alveolar and skeletal maxillary width in patients affected with UMLIA and BMLIA, respectively. Patients with MLIA also demonstrated a significant tendency for skeletal Class III, which could be attributed to maxillary hypoplasia and retrognathia.[2,6]

Attempts to resolve the controversy over the choice of a better treatment method would probably be in vain. However, it cannot be denied that temporary anchorage devices (TADs) have revolutionized the treatment of malocclusion with regard to treatment outcomes and thus have expanded the limits of conventional orthodontics.

Optimal locations for TADs have been precisely determined, which facilitates predictable treatment outcomes. There appears to be more space for their placement in the mandible than in the maxilla.[11] Areas between the second premolar and the first molar in the maxilla, between the first and second premolars, and between the first and second molars in the mandible are the safest zones.[12]

The novel approach or new opportunities of anchorage reinforcement and all hitherto presented evidence-based approaches to MLIA give rise to a scientific question: is it possible to substitute canines using TADs without compromising the dimension of the maxilla and achieve esthetically pleasing results if a patient with congenitally missing lateral incisors does not present with Class II malocclusion? This prospective cohort study was designed to validate whether closing the space by the protraction of the maxillary dentition using mandibular skeletal anchorage devices is a viable treatment option for patients with MLIA and Class I or Class III skeletal pattern.

Based on the contemporary techniques and approaches available, the following hypotheses were established and related to the novel concept of MLIA treatment in Class I and III patients: (1) protraction of the maxillary dentition and obtaining functional and esthetic occlusion are possible regardless of the deficiency of the maxilla, and (2) canine substitution of the missing lateral incisors neither violates axial inclination of the central incisors nor deteriorates a patient's facial features.

MATERIAL AND METHODS

The study project obtained approval by 2 ethics committees: (1) the Ethics Committee of the Wrocław Medical University (Wrocław, Poland; approval no. 48/XV2/2011) on October 24, 2013, and (2) the Ethics Committee of the Lower Silesian Medical Union (Wrocław, Poland; approval no. KB/517/2013) on July 24, 2013.

The study sample was composed of generally healthy patients who met the following criteria: (1) 2 congenitally missing maxillary lateral incisors or 1 missing maxillary lateral incisor and a riziform (ie, peg-shaped) contralateral incisor; (2) skeletal Class I or Class III tendency or a mild skeletal Class III, which presented as follows: (i) an average ANB value of 0° (ranging from −12° to 4°) and (ii) an average Wits appraisal value of −3 mm (ranging from −14 mm to 4 mm); and (3) a dentoalveolar discrepancy in the mandible of <5 mm; no extractions required in the mandible, except for the third molars.

After the patients had been provided with a detailed explanation of the advantages and disadvantages of canine substitution vs conventional space opening for implant placement, based on the literature, they were asked to sign a consent form. The study group ultimately consisted of the first consecutive 30 individuals who accepted the treatment plan with a canine substitution (11 Class I and 19 Class III).

Before beginning treatment (T1), initial records were obtained for all patients, which included extra- and intraoral photographs. Digital models were obtained by scanning the plaster models (TRIOS 3 Mono; 3Shape, Copenhagen, Denmark); orthopantomograms and lateral cephalogram radiographic images were also acquired.

All initial lateral cephalograms were calibrated and introduced into the software for analysis (Joe Ceph; Rocky Mountain Orthodontics, Denver, Colo). A single operator obtained all measurements, although 10 randomly selected radiographic images were cross-evaluated with regard to the points insertion accuracy.

Treatment was initiated with a rapid palatal expander (RPE) mounted in the maxilla, with banding and bonding the mandibular dental arch (single standard edgewise 0.022-inch brackets; canine brackets with hooks, when available; otherwise, a Kobayashi ligature was attached to the canine bracket), and with the insertion of an initial round nickel-titanium archwire (0.016 inch). Subsequently the patients were asked to wear Class III elastics (0.25 inch, 6 oz) from the maxillary first molar hooks to the mandibular canines for 24 hours per day, along with the activation of the RPE at 0.25 mm per day for 2 weeks (or until the lateral crossbite was corrected in patients who had a lateral crossbite).

Heat-activated NiTi wire (0.019 × 0.025 inch) was the second archwire. Patients continued to wear Class III elastics as needed to align and level the curve of Spee, with the control of the mandibular incisors. A stainless steel archwire (0.019 × 0.025 inch) was inserted after the correction of all rotations. At this stage, the patients were asked to stop wearing the Class III elastics.

A panoramic radiograph was made to ensure there were (1) root parallelism and (2) sufficient space for placing the TAD (FH 1817-08, AbsoAnchor; Dentos, Inc, Daegu, Korea). At this stage, the RPE was removed, and the maxillary was arch bonded, and the following archwire sequence was introduced: (1) 0.016-inch NiTi wire, (2) 0.019 × 0.025-inch heat-activated NiTi wire, and (3) 0.020 × 0.025-inch stainless steel with closing loops positioned distally to the central incisors. Extraction of the peg-shaped contralateral lateral incisor (if present), correction of the maxillary midline, and placement of the TAD preceded the insertion of the closing archwire.

Two TADs were inserted in the following quadrants of the mandible: (1) between the canine and the first premolar or (2) between the premolars (depending on the root divergence). The TADs were placed in the junction of the attached gingiva and oral mucosa or shallower (ie, toward the attached gingiva) in the vestibulum, with an inclination of approximately 45° with respect to the dental axis. The TAD loading was applied 2 weeks later with Class III elastics (0.25 inch, 6 oz.) expanded to the maxillary second molars (Fig). On obtaining 1-2 mm or more of overjet overcorrection, the closing loops of the maxillary 0.020 × 0.025-inch stainless steel archwire were activated.

After the closure of the spaces between the lateral and central incisors, "up and down" elastics with or without Class III elastics on the TADs helped to monitor the overjet and the overbite and to maintain an overcorrection of 1-2 mm. Finally, "up and down" elastics were introduced to seat the occlusion from the maxillary arch to the mandibular arch or to the TADs, based on the smile arc course and the need for egression of the maxillary anterior teeth. After removing the TADs, maxillary and mandibular finishing archwires (0.020 × 0.025 inch) were inserted with intermaxillary elastics, if needed, until finishing the case with proper occlusion. For the retention protocol, a lingual retainer bonded from left mandibular canine to right first premolar and a removable thermoformed maxillary retainer were applied.

One month after debonding (T2), the final measurements were obtained, based on the same protocol as that at T1. At this point, a digital simulation of veneers was provided to help patients decide whether they wanted composite restorations to be performed by their restorative dentists.

All final lateral cephalograms were calibrated and introduced into the software for analysis (Joe Ceph; Rocky Mountain Orthodontics). A single operator obtained all measurements, although 10 randomly selected radiographic images were cross-evaluated with regard to the points insertion accuracy. Reproducibility between measurements was tested using the intraclass correlation coefficient and its 95% confidence interval. For all measurements, the intraclass correlation coefficient (intraclass correlation coefficient >0.990) was very high, indicating an excellent reproducibility. All initial and final 3D model files were loaded into a software program (OrthoAnalyzer; 3Shape), which enabled the assessment of the occlusal treatment outcomes, based on the peer assessment rating (PAR) index, as originally described in 1992.[13]

At least 6 months after the end of treatment, 2 photographs of the close-up view of the patient's smile before and after treatment were sent to each patient, along with a visual scale with scores ranging from 0 to 10. A third party was asked to apply an instant messaging phone application (WhatsApp, Inc, Menlo Park, Calif). All patients were asked for a self-assessment of the treatment outcome in terms of smile

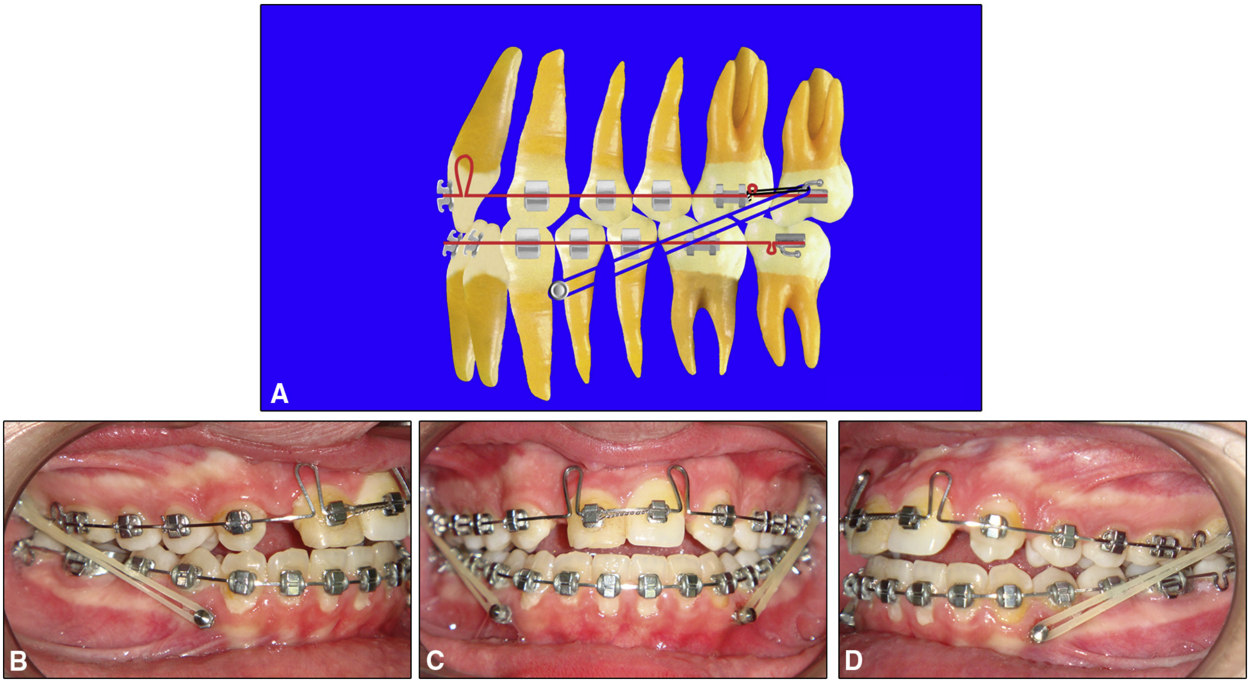

Fig. Class III elastics on the TADs and the closing maxillary archwire. **A,** Schematic drawing. **B-D,** In vivo intraoral images showing the temporary intraoral skeletal anchorage device.

esthetics. To verify the 2 hypotheses in the aim of the present study, all pretreatment and posttreatment measurements were compared and analyzed. The null hypothesis was that there is no measurable improvement from T1 to T2.

Statistical analysis

Statistical analyses were conducted using a software program (SPSS for Windows, version 22.0, Chicago, Ill). The level of significance was set at $P < 0.05$. Normality distribution was assessed using the Kolmogorov-Smirnov test. Paired Student t tests or Wilcoxon tests were used for comparison of continuous variables between before and after treatment. The 95% confidence interval of the mean measurements for each parameter was also calculated.

RESULTS

Thirty patients (12 male and 18 female; mean age, 16.3 $\pm$ 4.9 years) were included in this study. The mean age of the male patients and female patients was 15.4 $\pm$ 4.6 years and 16.9 $\pm$ 5.2 years, respectively. The mean effective treatment time lasted 32 $\pm$ 6.2 months and ranged from 22 to 43 months. Eight patients decided to have their canines recontoured. All variables studied in this project had a normal distribution. T1 and T2 photographs of 3 patients are available as Supplemental materials; available at www.ajodo.org.

The mean changes in the cephalometric values achieved during orthodontic treatment were calculated by comparing the T1 and T2 measurements (Tables I and II). A significant increase in the SNA by 1.3° ($P = 0.025$), ANB by 2° ($P < 0.001$), and Wits appraisal by 5.27° ($P < 0.001$) coincided with an insignificant decrease in the SNB by 0.6° ($P = 0.179$). These findings altogether proved (1) the efficient forward movement of the A point and (2) the simultaneous maintenance of the B point position. Mesial movement of the maxilla was eventually confirmed by a significant increase in the U6Ptv ($P < 0.001$). The mean value of the mesialization of the molars reached 5.27 mm (Table II).

A significant increase in the Frankfort plane to mandibular incisor axis by 3.97° ($P = 0.004$), together with a significant decrease in both the mandibular incisor axis to mandibular plane (IMPA) by 3.7° ($P = 0.002$) and the mandibular incisor axis to NB line (L1-NB) ($P = 0.001$), showed favorable retroclination and the distal movement of the mandibular incisors due the orthodontic treatment. The maxillary incisors also demonstrated favorable displacement. However, none of the changes was statistically significant: the maxillary incisor axis to SN line (U1-SN) changed by

Table I. The mean values of the cephalometric parameters measured at the T1 and T2 stages

	Initial (T1) (n = 30)		Final (T2) (n = 30)		
	Mean (SD)	95% CI	Mean (SD)	95% CI	P value
SNA	79.47 (3.72)	78.14, 80.80	80.77 (3.36)	79.57, 81.97	0.025*
SNB	79.27 (3.58)	77.99, 80.55	78.67 (3.82)	77.30, 80.03	0.179
ANB	0.07 (3.62)	−1.23, 1.36	2.07 (2.42)	1.20, 2.93	0.000*
FMA	22.50 (5.59)	20.50, 24.50	22.20 (6.84)	19.75, 24.65	0.576
IMPA	95.00 (7.18)	92.43, 97.57	91.30 (7.49)	88.62, 93.98	0.002*
FMIA	62.60 (6.88)	60.14, 65.06	66.57 (7.97)	63.71, 69.42	0.004*
OccPl	6.17 (4.58)	4.53, 7.81	2.53 (5.12)	0.70, 4.36	0.001*
L1-NB	25.50 (6.06)	23.33, 27.67	20.97 (5.94)	18.84, 23.09	0.001*
U1-SN	104.50 (5.22)	102.63, 106.37	105.30 (8.13)	102.39, 108.21	0.533
U1-NA	25.00 (6.23)	22.77, 27.23	24.73 (7.39)	22.09, 27.38	0.820
NL-angle	106.93 (11.14)	102.95, 110.92	106.10 (11.03)	102.15, 110.05	0.712
AO-BO	−2.87 (4.08)	−4.33, −1.41	2.23 (3.03)	1.15, 3.32	0.000*
U6ptv	17.33 (3.81)	15.97, 18.70	22.60 (3.18)	21.46, 23.74	0.000*
E-LL	−2.83 (2.65)	−3.78, −1.88	−4.17 (2.72)	−5.14, −3.19	0.000*
E-UL	−5.80 (3.13)	−6.92, −4.68	−5.27 (2.57)	−6.19, −4.35	0.202
LL-UL	2.90 (1.94)	2.21, 3.59	1.03 (1.63)	0.45, 1.61	0.000*

SD, standard deviation; CI, confidence interval.
*The mean difference is significant (*P* <0.05).

0.8° (*P* = 0.533), maxillary incisor axis to NA line (U1-NA) by 0.27° (*P* = 0.820), nasolabial angle (NL-Ang) by 0.83° (*P* = 0.712), and upper lip to E-plane (E-UL) by 0.53 mm (*P* = 0.202).

A significant increase in the lower lip to E-plane (E-LL) by 1.34 mm (*P* <0.001) and a decrease in the LL-UL by 1.87 mm (*P* <0.001) favorably changed the lip profile as a result of the applied biomechanics, whereas the upper lip remained unaffected. No significant changes occurred in the E-UL and NL-Angle parameters (*P* >0.05).

Descriptive statistics of weighted and nonweighted PAR indexes are presented in Table III. The mean values of the weighted PAR index and nonweighted PAR index significantly decreased after orthodontic treatment (*P* <0.001; Table IV).

Table V presents the comparison of the initial and final smile evaluations. In general, the mean visual analog scale scores significantly increased after orthodontic treatment (*P* <0.001).

DISCUSSION

In this study, the null hypothesis was rejected. Multiple studies in the scientific database over the years have compared the major alternatives for MLIA treatment—canine substitution or restorative replacement. Despite the advanced and evidence-supported dispute, no clear conclusion has been reached.[7,8] Thus, the objective of this study was not to compare these options or to determine the superiority of one treatment option over another. Rather, the prospective clinical objectives of this study focused on assessing the cephalometric, dental, and occlusal changes; the soft tissue profile; and the smile esthetics in Class I and Class III patients with MLIA who were treated with canine substitution. The goal was to determine whether such an approach could provide functional occlusion and yield esthetically pleasing results and could, therefore, be adopted as a viable and efficient treatment protocol for these patients.

In the available literature regarding the epidemiology of MLIA, reports demonstrate that this abnormality or disturbance is not always bilateral. However, it is not rare to find peg-shaped lateral incisors when the contralateral incisor is congenitally missing,[4-6,14-16] which was also observed in the current study. If MLIA occurs in Class I or Class III patients, the conventional protocol is to maintain the conically shaped incisor, which subsequently undergoes prosthetic or conservative recontouring. However, the current treatment approach assumed canine substitution; therefore, a decision was taken to extract the microdontic teeth and to treat these patients as bilateral agenesis. This concept was aimed at (1) saving the patient from invasive restorations and (2) maintaining symmetrical biomechanics.

Woodworth et al[17] recommended a mechanotherapy to open the mandibular plane to increase the vertical dimension and mesialization of the lateral teeth. Such a mechanism prevents worsening the Class III tendency.

Table II. The results of subtracting the initial mean values from the final mean values of the cephalometric parameters measured at the T1 and T2 stages

	Initial (T1) mean	Final (T2) mean	Mean difference (final - initial)
SNA final – SNA initial	79.47	80.77	1.3
SNB final – SNB initial	79.27	78.67	−0.6
ANB final – ANB initial	0.07	2.07	2
FMA final – FMA initial	22.50	22.20	−0.3
IMPA final – IMPA initial	95.00	91.30	−3.7
FMIA final – FMIA initial	62.60	66.57	3.97
OccPl final – OccPl initial	6.17	2.53	−3.64
L1-NB final – L1-NB initial	25.50	20.97	−4.53
U1-SN final – U1-SN initial	104.50	105.30	0.8
U1-NA final – U1-NA initial	25.00	24.73	−0.27
NL-angle final – NL-angle initial	106.93	106.10	−0.83
AO-BO final – AO-BO initial	−2.87	2.23	5.1
U6Ptv final – U6Ptv initial	17.33	22.60	5.27
E-LL final – E-LL initial	−2.83	−4.17	−1.34
E-UL final – E-UL initial	−5.80	−5.27	0.53
LL-UL final – LL-UL initial	2.90	1.03	−1.87

Table III. Comparisons of changes in PAR and PARw

	Minimum	Maximum	Mean (SD)
PAR initial	12	34	22 (6)
PAR final	0	5	0.8 (1)
PAR initial – PAR final	11	32	21 (6)
PARw initial	4	181	57 (6)
PARw final	0	17	1 (3)
PARw initial – PARw final	−13	181	56 (52)

PAR, peer assessment rating; PARw, peer assessment rating weighted.

Table IV. Statistical evaluation of the occlusal changes after orthodontic treatment

	Initial (T1) (n = 30)		Final (T2) (n = 30)		
	Mean (SD)	95% CI	Mean (SD)	95% CI	P value
PAR	21.87 (6.02)	19.72, 24.02	0.77 (1.07)	0.38, 1.15	0.000*
PARw	56.80 (51.39)	38.41, 75.19	1.00 (3.11)	−0.11, 2.11	0.000*

SD, standard deviation; CI, confidence interval; PAR, peer assessment rating; PARw, peer assessment rating weighted.
*The mean difference is significant ($P < 0.05$).

Table V. Statistical evaluation of the smile changes after orthodontic treatment

	Initial (T1) (n = 30)		Final (T2) (n = 30)		
	Mean (SD)	95% CI	Mean (SD)	95% CI	P value
VAS	1.13 (1.63)	0.55, 1.72	9.03 (1.03)	8.66, 9.40	0.000*

SD, standard deviation; CI, confidence interval; VAS, visual analog scale.
*The mean difference is significant ($P < 0.05$).

It also minimizes retraction of the maxillary incisors, which adversely opens the NL-Ang. This goal may be achieved using a facemask or reverse-pull headgear.[17,18] Nevertheless, the current designed novel treatment concept follows the "*primum non nocere*" standard, in which a fundamental modality was applied: orthodontic fixed appliances supported by TADs, which have proved to efficiently prevent the adverse reaction forces in the treatment of many types of malocclusions.[19-31] In this manner, the concept of Woodworth et al[17] may have been realized. By applying Class III elastics from the maxillary molars to the mandibular TADs, the facemask can be replaced as well as the need for more cooperation.

By choosing this approach, the generally approved protocol of managing MLIA is tested in Class I or Class III patients who have no indications for tooth extraction in the mandible and in whom space opening and restorative and implant replacement of the missing lateral incisor are theoretically the only therapeutic solutions. By contrast, it was shown that closing the space resulting from agenesis of the lateral incisors with the aid of TADs provides satisfactory results, even when the patient has a concave profile.

The current results validated the concept and the goal of the study. An increase in the ANB and the Wits appraisal from before to after the treatment of all patients and the maintenance of the SNB value helped correct the skeletal Class III malocclusion (ie, mesialization of the maxilla without violating the position of the mandible). Furthermore, statistically significant mesial movement of the maxillary first molars by 5.27 mm indicates that this movement is the forward displacement of the maxillary lateral teeth that primarily contributed to the space closure. If so, then preserving the distal movement of the maxillary incisors helped to control the upper lip position and the profile. The present treatment protocol closed the space of the missing maxillary lateral incisors and improved the sagittal position of the whole maxilla.

An insignificant difference in the values, especially the U1-SN, U1-Na, NL-Ang, and E-UL parameters, was entirely inconsistent with what for years has been the main contraindication for canine substitution in patients with MLIA and skeletal Class I or Class III. Woodworth et al[17] analyzed the effects of space closure in such patients. They compared the pretreatment and posttreatment records of 22 patients who underwent bilateral space closure. They found that the inclination of the incisors did not change. However, they observed some bodily movement that resulted in the retraction of the upper lip (which was more significant in female patients) and consequently an increase in the NL-Ang by 5° to 10°. In the current sample, the maxillary incisors did not alter their inclinations in relation to the NA or SN lines; the NL-Ang also remained unchanged. Even if the stable position of the incisors primarily resulted from the application of TADs in the present treatment protocol, the use of standard edgewise brackets with zero torque, which counteracts labial protrusion (an adverse effect of the mesializing forces), may also have played a beneficial role.

The E-UL parameter did not change with treatment, but the E-LL parameter significantly decreased at the T2 stage, as did the LL-UL parameter. The present treatment approach consequently preserved the profile and improved it in patients by securing a more harmonious relationship among the upper lip, lower lip, and E-plane of Ricketts.

Mesial movement of the maxillary dentition without violation of the maxillary incisor torque and with simultaneously occurring efficient retroclination of the mandibular incisors secured an appropriate overbite. This finding proved that the presented protocol helped to achieve normal occlusion and esthetic facial features in patients with MLIA and Class I or Class III malocclusions. Use of Class III elastics and the RPE at the initial treatment stage undoubtedly and efficiently contributed to the success of this approach, although the advantages of the treatment may be minimized if the patient is not very cooperative. Applying the Class III elastics early in the treatment allowed us to maintain the mandibular incisor sagittal position during the leveling of the mandibular curve of Spee—the mean IMPA value significantly decreased after the orthodontic treatment. This finding is in contrast to the results obtained with the use of other systems such as those described by Wilmes et al[30] and Rosa and Zachrisson,[32] which do not control the labial proclination of the mandibular incisors. Furthermore, the early use of the RPE corrected the crossbite and skeletal Class III malocclusion, which are not rare in patients with lateral incisor agenesis.[2,6]

The skeletally anchored palatal expanders could certainly be applied while utilizing splinted palatal TADs.[31,33-36] A compliance-free design with the stability of palatally inserted screws securing the devices is their distinct advantage. However, the present protocol focused on space closure, as well as bite jumping. Thus, applying Class III elastics was necessary to correct the intermaxillary relationship. The reported success rate of miniplates[37-39] and their customized placement mode[40] suggests they can be used to apply traction. However, it has been proven that microscrews inserted in the interradicular spaces of the mandible efficiently withstand orthodontic loading.[41,42] Furthermore, invasive surgery related to the miniplates still does not exempt patients from conscientiously wearing Class III elastics. For this reason, the insertion protocol was meticulously followed, which may have provided a high success rate when treating the current sample with TADs. General anesthesia administered during more invasive surgical procedures achieves the same treatment goal as using single microscrews, the application of which necessitates no special expertise other than knowing how to insert these devices.

During the study period, there was a failure with the TADs. The high success rate in the current study might be because of the location, in the cortical bone and in the attached gingiva, and the elapsed time between placement and loading (2 weeks). No TADs were loaded before being sure of clinical stability.

In a recent systematic review by Alharbi et al,[43] the type of loading (intermittent or continuous) was not included as a risk factor. The type of the gingivae and smoking had a statistically significant effect. Wu et al[44] concluded that an intermittent loading regimen is more favorable than a continuous force for obtaining stability of TADs, giving more advantage to using Class III elastics.

Chaimanee et al[12] conducted a study to determine the zones for TAD placement that had a low risk of dental root injury in the maxilla and the mandible. The authors analyzed the periapical radiographs of 60 patients and measured each interradicular space at different distances from the alveolar crest. They found that the spaces between the second premolar and the first molar in the maxilla, and between the first and the second premolars, and the first and the second molars in the mandible were the widest or the most suitable areas for the TADs insertion. In the Chaimanee study,[12] the investigators also found evidence that the availability of the in-between root space is influenced by the inclination of the adjacent teeth. Tipped teeth are associated with a reduced interradicular space; however, this space was increased if the teeth are upright. Therefore, in the present sample, radiographic images were obtained just before inserting the TADs to ensure that the root divergence secured the space necessary for the placement of the screws between the canine and the first premolar. This location ensured that as much of a horizontal force vector as possible was delivered by the Class III elastics attached to TADs inserted in the compact mandibular bone. On evaluating the orthopantomogram, brackets were rebonded (if necessary), which subsequently delayed the insertion of the screw until after the required alignment of the roots had occurred.

It has been reported that, with canine substitution, a tooth size discrepancy is created, and this factor may affect occlusion.[8,16,45] In this study, some patients did not have perfect interdigitation. However, the PAR and the weighted PAR indexes significantly decreased after orthodontic treatment ($P < 0.001$). Therefore, the occlusion was satisfactorily corrected and improved.

The periodontal status or issues influencing the temporomandibular joint are other concerns in the present study that need to be discussed. Rosa et al[46] reported a 10-year follow-up of patients with MLIA treated with canine substitution. All of these patients had healthy and stable periodontal tissues, as did the individuals with no missing teeth and no need for extraction in the control group; there was no attachment loss for the uneven bone crests. Silveira et al[10] also concluded in their systematic review that tooth-supported dental prostheses of the maxillary lateral incisor had worse scores for the periodontal indexes, compared with the scores for orthodontic space closure. It has also been reported that the signs and symptoms of temporomandibular disorder or occlusal function show no association with the presence or absence of a Class I relationship of the canines.[8,16,46-48] None of the patients from this study presented with periodontal or temporomandibular disorder symptoms after treatment. As such, the treatment method proposed in the current study does not seem to jeopardize periodontal health or normal function of the temporomandibular joint.

Robertsson and Mohlin[45] conducted a study in which they evaluated the occlusal and periodontal status of 50 MLIA patients treated with space closure and canine substitution or treated with space opening for prosthetic replacement. The patients were surveyed about the esthetics of their treatment results. Most patients in the group with the space closure were satisfied with their appearance, although they disliked that the canine shade was darker than that of the adjacent teeth. By contrast, the other group of patients in whom space was reopened was modestly satisfied. Gingivitis and plaque accumulation that was observed more frequently in the latter group may have contributed to the deterioration in esthetic perception.

All of the patients who participated in the current study were satisfied with their smile restoration. The subjective evaluation of the treatment outcomes, based on the visual analog scale of the pretreatment and posttreatment smile photographs (ie, after composite restorations, if the patient chose this option), were significantly different. This finding demonstrated final improvement in their esthetic perception of their smile.

It must be noted that, with space closure, the canines and the first premolars are not in the positions that they would normally occupy in the dental arch. As such, occlusion, shape, and esthetics are affected by this treatment option. However, clinicians resort to different tips and techniques to avoid mediocre results. Biggerstaff in 1992[49] proposed using the slightly distal placement of the bracket on the first premolars to rotate the palatal cusps distally. This method eliminates working and balancing interferences and the need to minimize these cusps. In 1970, Tuverson[50] suggested inserting negative (ie, palatal) crown torque on the first premolar to simulate the canine root eminence. He also recommended a pronounced labial offset of the first premolar to better resemble the canine. Palatal root torque on the canine reduces its eminence, improves interproximal contact of the canine with the central incisor, and diminishes occlusal stress on the mandibular incisors.[15,48,50,51] It has also been recommended that customized intrusion of the first premolar and extrusion of the canine should be administered to correct the alignment of the gingival margin.[15,48] Grinding approximately 1 mm from the palatal surface of the canine should be performed at the beginning of treatment to prevent interfering with the mandibular incisors.[48,50] Recontouring of the canine (ie, mesiodistal grinding, incisal tip reduction, and labial surface flattening) is also required to simulate the shape of the lateral incisor.[15,50]

In this study group, palatal root torque on the canine was introduced to resemble the lateral incisor. The gingival margins were levelled, and reshaping was limited to merely grinding the canine tip. In this manner, occlusal equilibrium was achieved in patients in whom the palatal surface was interfering with the mandibular incisors. Neither mesiodistal nor labial surfaces needed enamel reduction. The final restoration of the canine with composites followed each patient's preferences, which were determined after a digital simulation.

CONCLUSIONS

The present study demonstrated that canine substitution for treating MLIA in patients presenting with Class I or Class III skeletal patterns can be a viable treatment option when achieved with mandibular TADs and Class III elastics.

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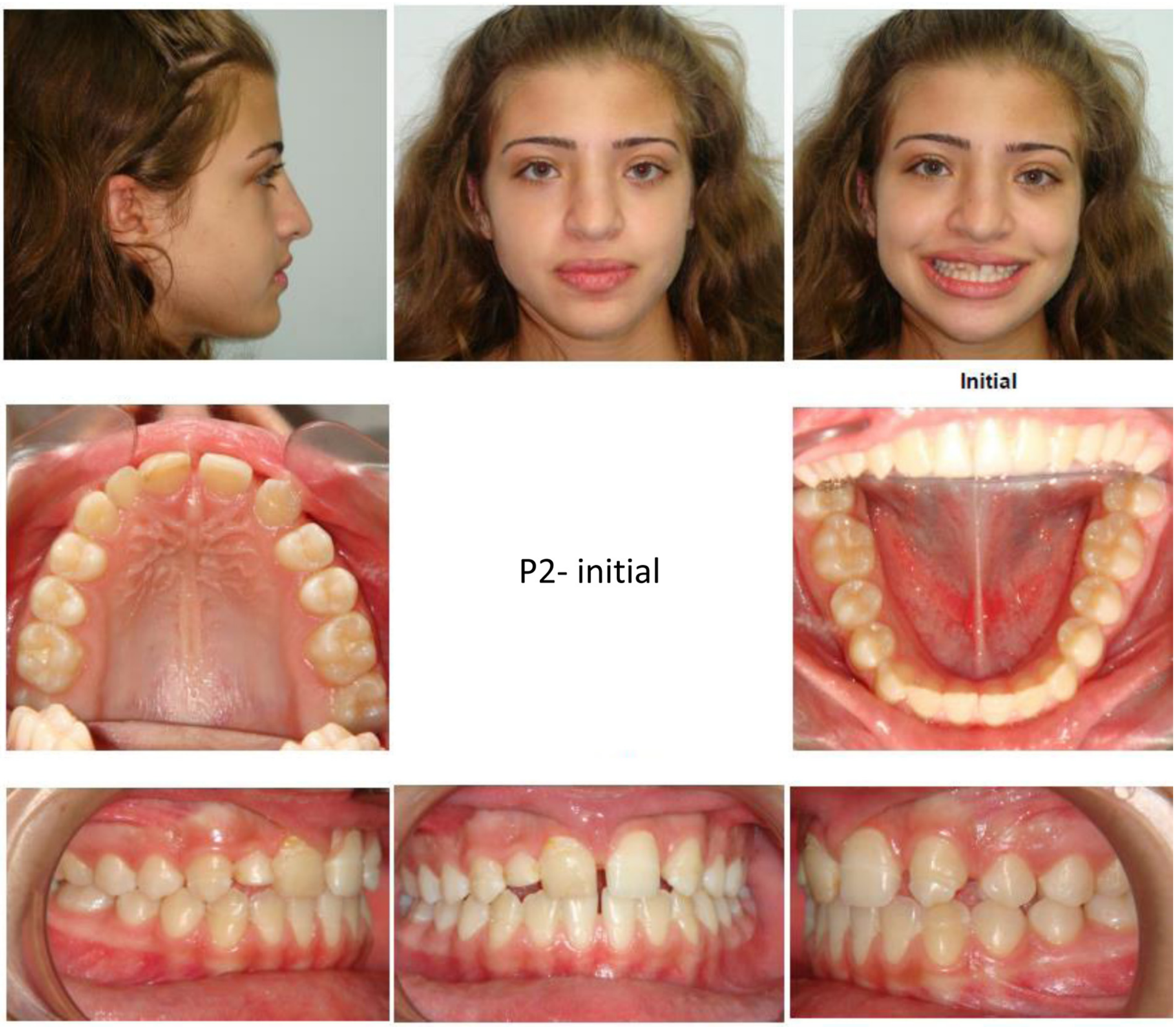
REFERENCES

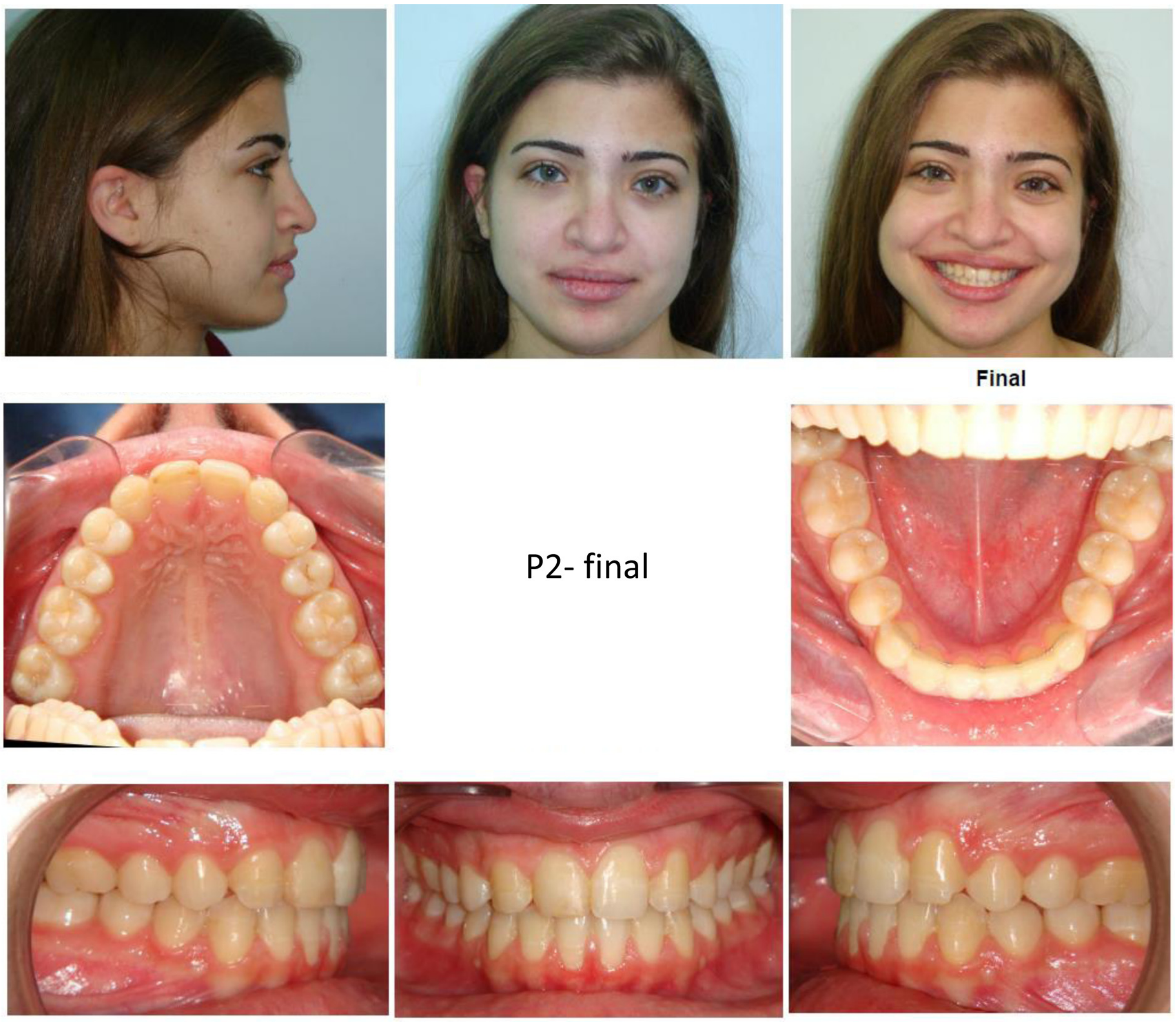
1. Alves-Ferreira M, Pinho T, Sousa A, Sequeiros J, Lemos C, Alonso I. Identification of genetic risk factors for maxillary lateral incisor agenesis. J Dent Res 2014;93:452-8.
2. Bassiouny DS, Afify AR, Baeshen HA, Birkhed D, Zawawi KH. Prevalence of maxillary lateral incisor agenesis and associated skeletal characteristics in an orthodontic patient population. Acta Odontol Scand 2016;74:456-9.
3. Kabbani T, Abdullah N, Rsheadat Y, Hassan MI. Prevalence of isolated maxillary lateral incisor agenesis in Syrian adolescents. J Orofac Orthop 2017;78:62-9.
4. Tai K, Park JH, Takayama A. Congenitally missing maxillary lateral incisor treated with atypical extraction pattern. J Clin Pediatr Dent 2011;36:11-8.
5. Citak M, Cakici EB, Benkli YA, Cakici F, Bektas B, Buyuk SK. Dental anomalies in an orthodontic patient population with maxillary lateral incisor agenesis. Dent Press J Orthod 2016;21:98-102.
6. Buyuk SK, Ozkan S, Benkli YA, Arslan A, Celik E. Evaluation of the skeletal and dental effects in orthodontic patients with maxillary lateral incisor agenesis. J Esthet Restor Dent 2017;29:284-90.
7. Zachrisson BU, Rosa M, Toreskog S. Congenitally missing maxillary lateral incisors: canine substitution. Point. Am J Orthod Dentofacial Orthop 2011;139:434, 436, 438 passim.
8. Kokich VO Jr, Kinzer GA, Janakievski J. Congenitally missing maxillary lateral incisors: restorative replacement. Counterpoint. Am J Orthod Dentofacial Orthop 2011;139:435, 437, 439 passim.
9. Schneider U, Moser L, Fornasetti M, Piattella M, Siciliani G. Esthetic evaluation of implants vs canine substitution in patients with congenitally missing maxillary lateral incisors: are there any new insights? Am J Orthod Dentofacial Orthop 2016;150:416-24.
10. Silveira GS, de Almeida NV, Pereira DM, Mattos CT, Mucha JN. Prosthetic replacement vs space closure for maxillary lateral incisor agenesis: a systematic review. Am J Orthod Dentofacial Orthop 2016;150:228-37.
11. Kau CH, English JD, Muller-Delgardo MG, Hamid H, Ellis RK, Winklemann S. Retrospective cone-beam computed tomography evaluation of temporary anchorage devices. Am J Orthod Dentofacial Orthop 2010;137:166.e1-5: discussion 166-167.
12. Chaimanee P, Suzuki B, Suzuki EY. "Safe zones" for miniscrew implant placement in different dentoskeletal patterns. Angle Orthod 2011;81:397-403.
13. Richmond S, Shaw WC, O'Brien KD, Buchanan IB, Jones R, Stephens CD, et al. The development of the PAR Index (Peer Assessment Rating): reliability and validity. Eur J Orthod 1992; 14:125-39.
14. Garib DG, Alencar BM, Lauris JR, Baccetti T. Agenesis of maxillary lateral incisors and associated dental anomalies. Am J Orthod Dentofacial Orthop 2010;137:732-3.
15. Park JH, Okadakage S, Sato Y, Akamatsu Y, Tai K. Orthodontic treatment of a congenitally missing maxillary lateral incisor. J Esthet Restor Dent 2010;22:297-312.
16. Kiliaridis S, Sidira M, Kirmanidou Y, Michalakis K. Treatment options for congenitally missing lateral incisors. Eur J Oral Implantol 2016;9(Suppl 1):S5-24.
17. Woodworth DA, Sinclair PM, Alexander RG. Bilateral congenital absence of maxillary lateral incisors: a craniofacial and dental cast analysis. Am J Orthod 1985;87:280-93.
18. Tabuchi M, Fukuoka H, Miyazawa K, Goto S. Skeletal Class III malocclusion with unilateral congenitally missing maxillary incisor treated by maxillary protractor and edgewise appliances. Angle Orthod 2010;80:405-18.
19. Park HS, Bae SM, Kyung HM, Sung JH. Micro-implant anchorage for treatment of skeletal Class I bialveolar protrusion. J Clin Orthod 2001;35:417-22.
20. Bae SM, Park HS, Kyung HM, Kwon OW, Sung JH. Clinical application of micro-implant anchorage. J Clin Orthod 2002;36: 298-302.
21. Park HS, Kyung HM, Sung JH. A simple method of molar uprighting with micro-implant anchorage. J Clin Orthod 2002;36: 592-6.
22. Giancotti A, Greco M, Mampieri G, Arcuri C. The use of titanium miniscrews for molar protraction in extraction treatment. Prog Orthod 2004;5:236-47.
23. Park HS, Kwon TG. Sliding mechanics with microscrew implant anchorage. Angle Orthod 2004;74:703-10.
24. Zaleska K. Wspolczesne metody zakotwiczenia w leczeniu pacjentow doroslych: Przeglad pismiennictwa, opis przypadku. Ortod Wspolcz 2004;6:11-7.
25. Antoszewska J. Class II, division 2 treatment supported by absolute anchorage case report. Dent Med Probl 2007;44:275-80.
26. Antoszewska J. Open bite treatment with Abso Anchor micro implants—a case report. Ortod Pol 2007;1:23-8.
27. Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 103:e6-15.
28. Papadopoulos MA. Orthodontic treatment of Class II malocclusion with miniscrew implants. Am J Orthod Dentofacial Orthop 2008; 134:604.e1-16.
29. Park HS, Kwon OW, Sung JH. Nonextraction treatment of an open bite with microscrew implant anchorage. Am J Orthod Dentofacial Orthop 2006;130:391-402.
30. Wilmes B, Drescher D, Nienkemper M. A miniplate system for improved stability of skeletal anchorage. J Clin Orthod 2009;43: 494-501.
31. Antoszewska J. Wykorzystanie tymczasowego zakotwienia korty-kalnego w leczeniu zaburzeń zgryzowo-zębowych. Poland: Rozprawa. Habilitacyjna Akad Med Wrocławiu: Wrocław; 2009. [In Polish].
32. Rosa M, Zachrisson BU. The space-closure alternative for missing maxillary lateral incisors: an update. J Clin Orthod 2010;44:540-9: quiz 561.
33. Wilmes B, Drescher D. A miniscrew system with interchangeable abutments. J Clin Orthod 2008;42:574-80: quiz 595.
34. Baumgaertel S, Razavi MR, Hans MG. Mini-implant anchorage for the orthodontic practitioner. Am J Orthod Dentofacial Orthop 2008;133:621-7.
35. Baumgaertel S. Maxillary molar movement with a new treatment auxiliary and palatal miniscrew anchorage. J Clin Orthod 2008; 42:587-9: quiz 596.

36. Ludwig B, Zachrisson BU, Rosa M. Non-compliance space closure in patients with missing lateral incisors. J Clin Orthod 2013;47:180-7.
37. De Clerck HJ, Cornelis MA, Cevidanes LH, Heymann GC, Tulloch CJ. Orthopedic traction of the maxilla with miniplates: a new perspective for treatment of midface deficiency. J Oral Maxillofac Surg 2009;67:2123-9.
38. Ludwig B, Glas B, Bowman SJ, Drescher D, Wilmes B. Miniscrew-supported Class III treatment with the hybrid RPE advancer. J Clin Orthod 2010;44:533-9: quiz 561.
39. Wilmes B, Nienkemper M, Ludwig B, Kau CH, Drescher D. Early Class III treatment with a hybrid hyrax-mentoplate combination. J Clin Orthod 2011;45:15-21: quiz 39.
40. Hourfar J, Kanavakis G, Goellner P, Ludwig B. Fully customized placement of orthodontic miniplates: a novel clinical technique. Head Face Med 2014;10:14.
41. Sung JH, Kyung HM, Bae SM, Park HS, Kwon OW, McNamara JA Jr. Microimplants in Orthodontics. Daegu, South Korea: Dentos; 2006.
42. Antoszewska J, Papadopoulos MA, Park HS, Ludwig B. Five-year experience with orthodontic miniscrew implants: a retrospective investigation of factors influencing success rates. Am J Orthod Dentofacial Orthop 2009;136:158.e1-10.
43. Alharbi F, Almuzian M, Bearn D. Miniscrews failure rate in orthodontics: systematic review and meta-analysis. Eur J Orthod 2018;40:519-30.
44. Wu Y, Xu Z, Tan L, Tan L, Zhao Z, Yang P, et al. Orthodontic mini-implant stability under continuous or intermittent loading: a histomorphometric and biomechanical analysis. Clin Implant Dent Relat Res 2015;17:163-72.
45. Robertsson S, Mohlin B. The congenitally missing upper lateral incisor. A retrospective study of orthodontic space closure versus restorative treatment. Eur J Orthod 2000;22:697-710.
46. Rosa M, Lucchi P, Ferrari S, Zachrisson BU, Caprioglio A. Congenitally missing maxillary lateral incisors: long-term periodontal and functional evaluation after orthodontic space closure with first premolar intrusion and canine extrusion. Am J Orthod Dentofacial Orthop 2016;149:339-48.
47. Silveira GS, Mucha JN. Agenesis of maxillary lateral incisors: treatment involves much more than just canine guidance. Open Dent J 2016;10:19-27.
48. Lombardo L, D'Ercole A, Latini MC, Siciliani G. Optimal parameters for final position of teeth in space closure in case of a missing upper lateral incisor. Prog Orthod 2014;15:63.
49. Biggerstaff RH. The orthodontic management of congenitally absent maxillary lateral incisors and second premolars: a case report. Am J Orthod Dentofacial Orthop 1992;102:537-45.
50. Tuverson DL. Orthodontic treatment using canines in place of missing maxillary lateral incisors. Am J Orthod 1970;58:109-27.
51. Kravitz ND, Miller S, Prakash A, Eapen JC. Canine bracket guide for substitution cases. J Clin Orthod 2017;51:450-3.

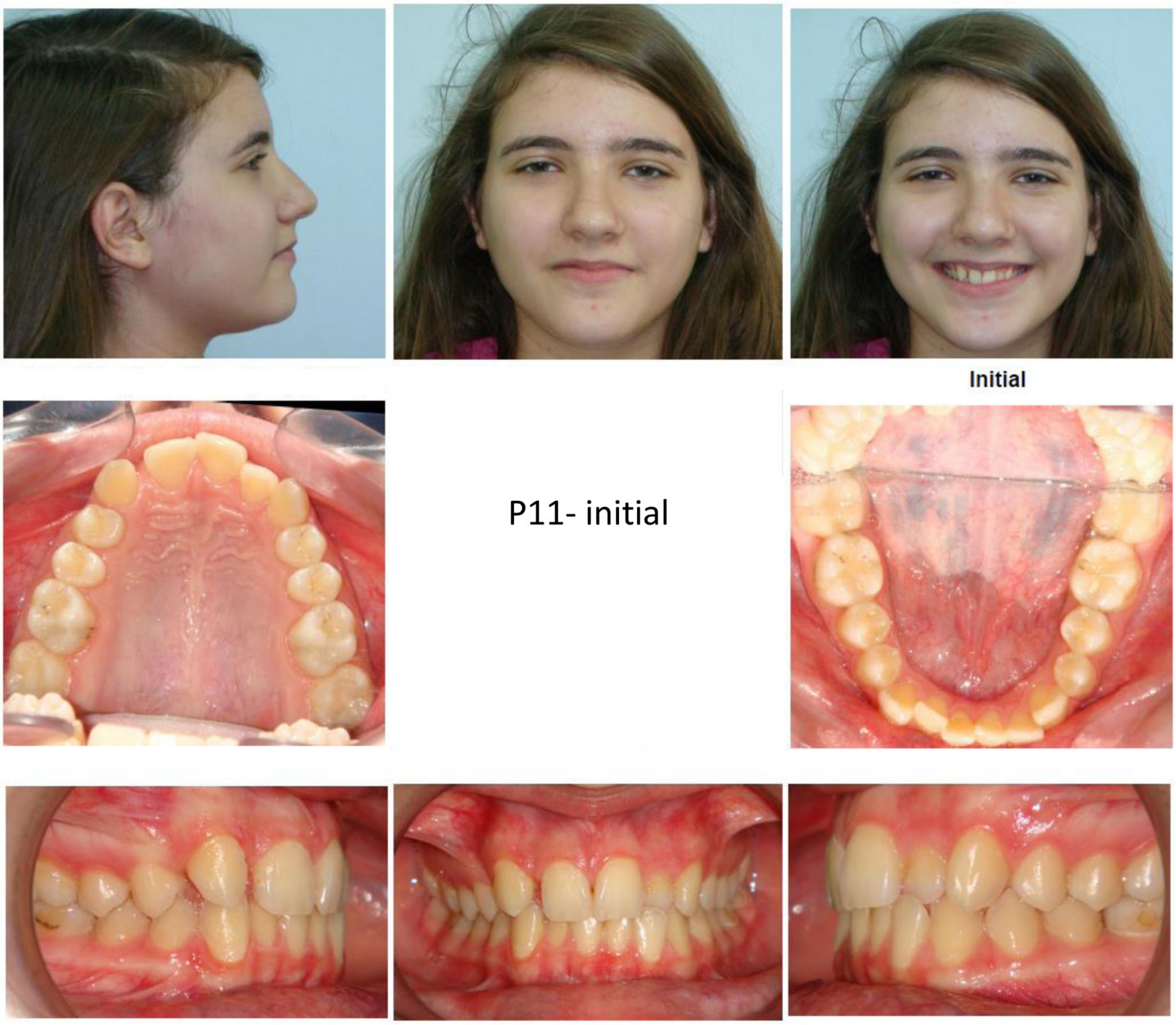
APPENDIX



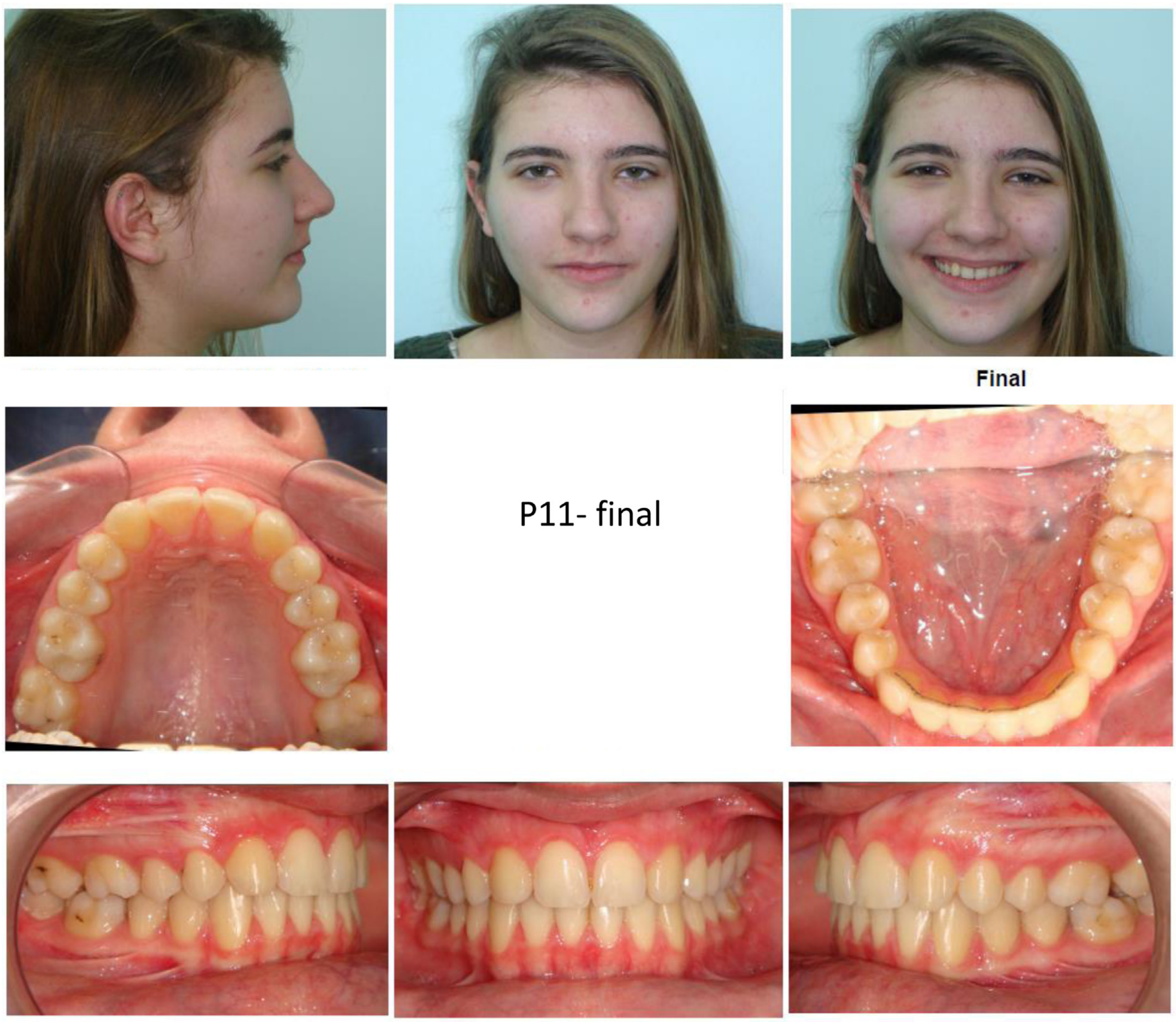
Supplementary Fig 1. P2-initial.



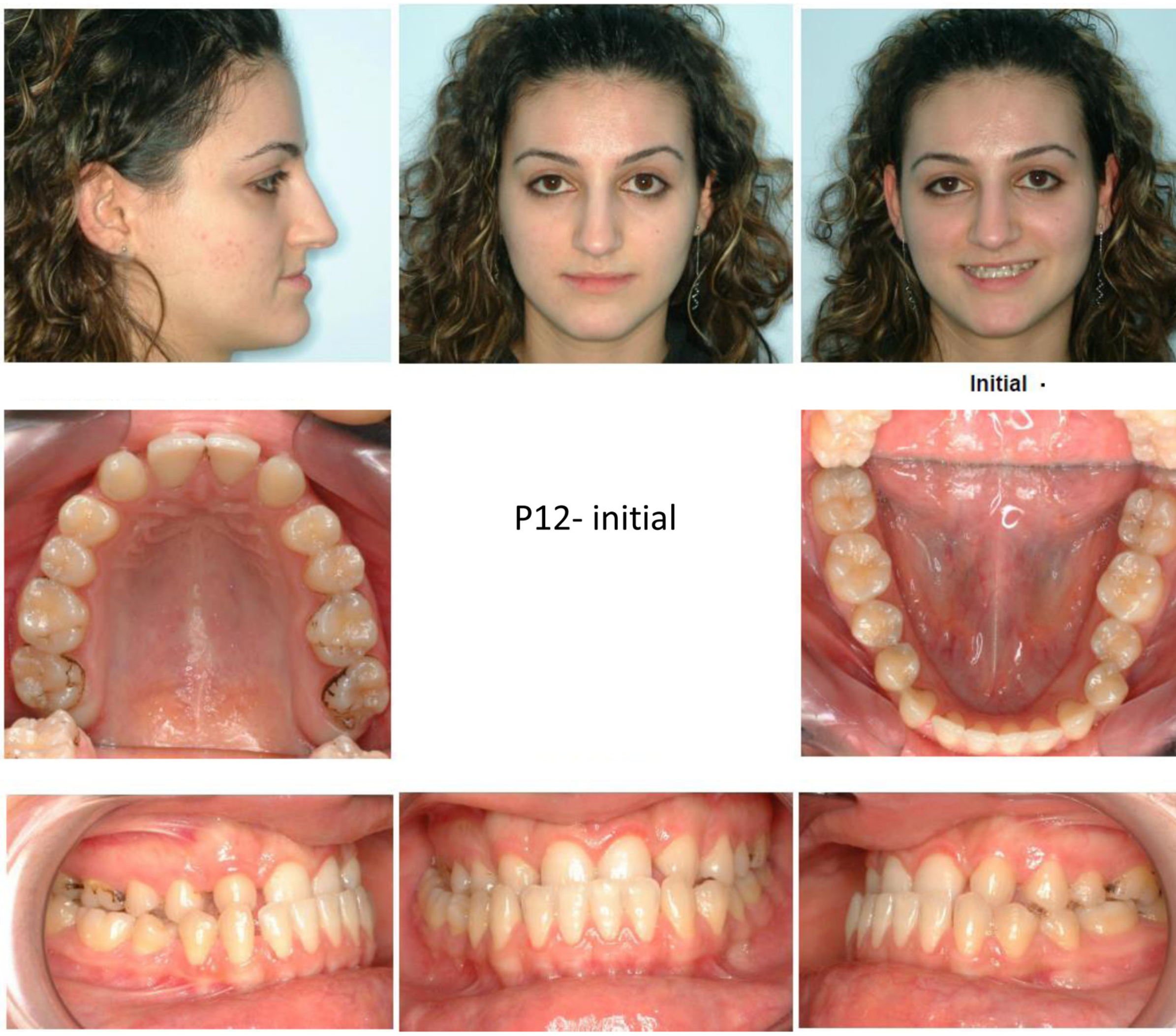
Supplementary Fig 2. P2-final.



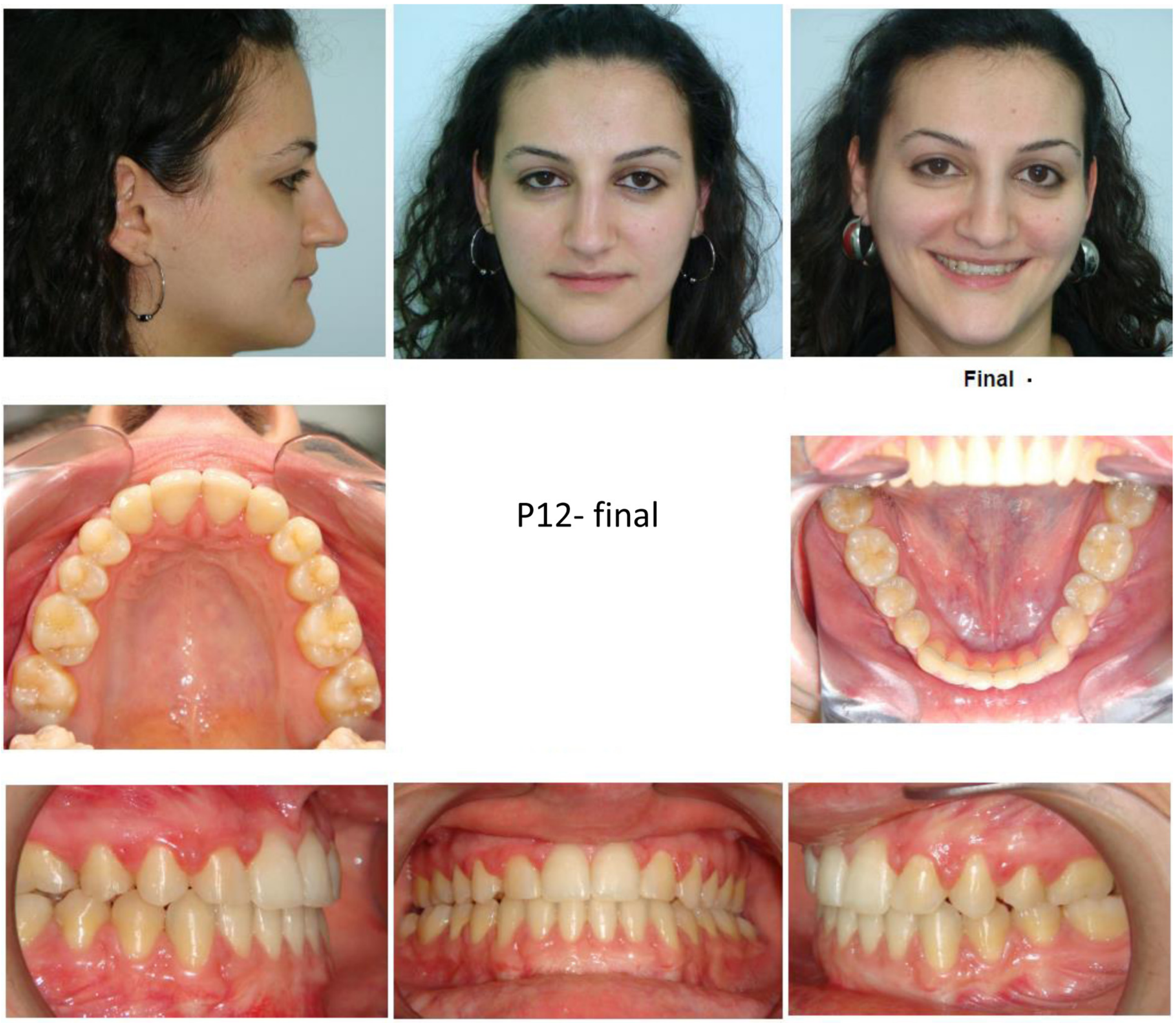
Supplementary Fig 3. P11-initial.



Supplementary Fig 4. P11-final.



Supplementary Fig 5. P12-initial.



Supplementary Fig 6. P12-final.