Original Article

Effect of maxillary and mandibular extrusion arches on dentoskeletal changes in adults with anterior open bite: a quantitative analysis

Tasneem Hammad[a]; Hassan Moussa[c]; Wessam Marzouk[b]; Hanan Amin Ismail[b]

ABSTRACT

Objective: To quantify dentoskeletal changes accompanying the use of extrusion arches during the treatment of anterior open bite (AOB) in adults.

Materials and Methods: A total of 23 adult patients with an AOB of –3.05 mm ± 1.27 mm were treated with upper and lower extrusion arches after the alignment phase. Lateral cephalograms were taken before placement of the extrusion arch, immediately after closure of the open bite (T2), and at the end of orthodontic treatment (T3). Data were statistically analyzed using repeated-measures analysis of variance and the Bonferroni post hoc test for pairwise comparisons ($\alpha = 0.05$).

Results: Successful closure of AOB, with an overall change in overbite of 4.73 ± 1.93 mm, was achieved in an average of 3.8 months and remained stable at T3. Upper and lower incisors were significantly extruded by 2.05 mm ± 0.72 mm and 2.54 mm ± 1.63 mm, respectively, and significantly retroclined by 6.36° ± 1.63° and 8.45° ± 3.83°, respectively, with a resultant increase in the interincisal angle of 12.80° ± 2.09°. Statistically significant intrusion and mesial tipping ($P <$ .001) of the maxillary and mandibular first molars were observed at T2. Dentoskeletal changes remained stable at T3, except for a significant reduction of the mesial tipping of the maxillary and mandibular first molars.

Conclusions: The combined use of maxillary and mandibular extrusion arches resulted in significant favorable dentoskeletal changes that led to the successful closure of AOB during a short duration of treatment. (*Angle Orthod.* 2022;93:26–32.)

KEY WORDS: Open bite; Extrusion arch; One-couple force system; Extrusion; Intrusion; Cephalometry

INTRODUCTION

Treatment of adult patients with anterior open bite (AOB) represents a unique challenge because facial development has stopped and interceptive treatment is no longer an option.[1] This has sometimes led to routine combined surgical and orthodontic therapy for adult patients with AOB. Owing to the risk and expense of surgical procedures, patients may refuse to undergo any surgical intervention. Nonsurgical treatment includes extrusive mechanics to the anterior segments, intrusive mechanics to the posterior segments, or a combination of both.[2,3]

The extrusion arch is one of the approaches that has been used successfully in the treatment of AOB according to the orthodontic literature.[2,3] It is the opposite of the well-known, one-couple intrusion arch system, comprising an overlay arch with an asymmetric V bend that uses a determinate one-couple force system to extrude maxillary incisors and intrude first molars, thus tipping the occlusal plane and closing the AOB.[4]

Extrusion arches applied only to the maxillary dentition showed successful closure of AOB in the mixed dentition.[4] However, in cases with large AOB, the use of one maxillary arch might result in unsightly gingival display.[5] Therefore, the placement of a complementary mandibular extrusion arch, in addition to that in the maxillary arch, was used in the current study.

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Apart from a few published case reports,[3,6] no research studies reported a quantitative evaluation of the skeletal and dental changes of the determinate one-couple force system applied by extrusion arches in the treatment of the AOB in adult patients. Therefore, the aim of this study was to evaluate and quantify the dental and skeletal effects accompanying the use of maxillary and mandibular extrusion arches in the treatment of AOB in adult patients using lateral cephalometric measurements. The null hypothesis was that extrusion arches would not cause any dental or skeletal changes to close AOB in adults.

MATERIALS AND METHODS

Trial Design

This study was approved by the institutional review board at the Faculty of Dentistry, Alexandria University (IRB:00010556–IORG:0008839) as a clinical study. The trial was registered in Clinical Trials.gov (NCT04901221).

Sample Size Calculation

The sample size was planned to detect a mean change in incisor vertical position of −0.97, standard deviation (SD) of 1, at a minimum probability of 80% ($\alpha = 5\%$), following the study of Janakiraman et al.[7] The minimum required sample size was calculated to be 17 patients, increased to 23 to compensate for cases lost to follow-up. Sample size calculations were performed using MedCalc Statistical Software (MedCalc Software bvba, Ostend, Belgium).

Data Collection

Inclusion criteria were adult patients (aged $\geq$18 years) with full permanent dentition except for the third molars, mild to moderate AOB (2–5 mm) not requiring extraction treatment, and presentation of upper and lower incisors indicated for extrusion. However, patients with craniofacial malformations, temporomandibular joint disorders, excessive gum show during smiling, or increased incisal show at rest were excluded.

A total of 132 patients with AOB were initially screened for eligibility; 23 patients who met the inclusion criteria and agreed to participate in the study were included. A complete set of pretreatment intraoral and extraoral photographs, study casts, panoramic radiographs, and lateral cephalograms were taken for all participants. All patients were treated by the same operator in the Orthodontic Department at Alexandria University.

Alignment Phase

Initial alignment was done for all patients until reaching 0.016 $\times$ 0.022-inch continuous nickel-titanium archwire with conventional brackets (Roth prescription, 0.022 $\times$ 0.028-inch slot; Orthos, Ormco Corporation, Orange, Calif) bonded to all teeth according to the recommendations for ideal bracket placement by McLaughlin and Bennett.[8] Height gauges and periodontal probes were used to adjust and check bracket positions. Bands with triple tubes and double tubes were cemented to the maxillary and mandibular second molars, respectively, as occlusally as possible to avoid their extrusion during leveling.

Cephalometric Evaluation

Tooth-positioning jigs were constructed using 0.017 $\times$ 0.025-inch stainless steel wire at different lengths to distinguish between the right and left first molars.[7] The jigs were inserted into the auxiliary tubes of the first molars during the acquisition of lateral cephalograms.

Cephalometric evaluation of the dentoskeletal changes was done at the end of the leveling and alignment phase as a baseline record (T1). All lateral cephalograms were traced and measured on matte acetate paper by a single investigator. A total of 32 measurements were performed as illustrated in Figures 1, 2, and 3.

Intervention

Extrusion arches were custom-made from 0.016 $\times$ 0.022-inch stainless steel archwires with helices and V bends placed on both sides, 2–5 mm mesial to the molar tubes. They were inserted into the auxiliary tubes of the maxillary and mandibular first molars and then tied anteriorly over the main archwire distal to the brackets of the lateral incisors on both sides (Figure 4). The extrusive force was calibrated using a force gauge to be 100 grams as recommended by Isaacson and Lindauer.[2] Follow-up visits were scheduled every 3–4 weeks. The maxillary and mandibular extrusion arches were kept until an overbite of 1–2 mm was achieved (Figure 5), followed by cephalometric measurements (T2).

Following removal of the extrusion arches, patients were instructed to wear 3/16-inch medium intraoral vertical box elastics with 4.5-oz (128 g) force (Ortho Technology, Tampa, Fla, USA). They were placed in the buccal segments between the upper and lower premolars on both sides all day long except at meal times. At the end of orthodontic treatment, lateral cephalometric X-rays were taken (T3).

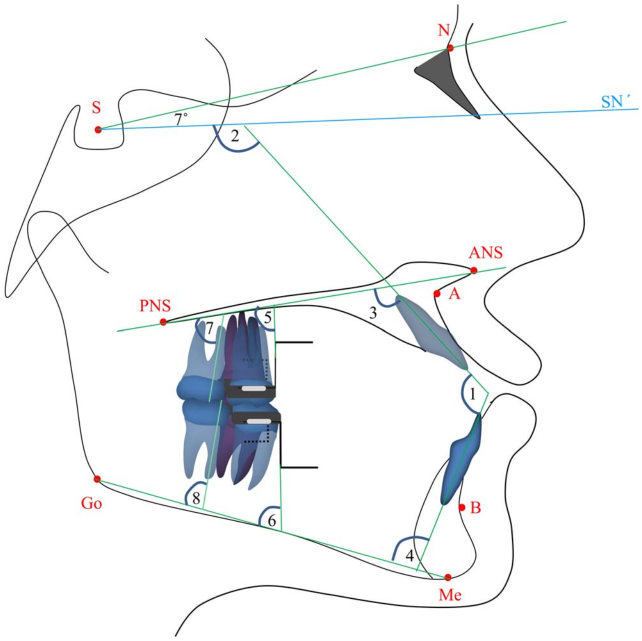

Figure 1. Schematic diagram showing the dental angular measurements on a cephalometric diagram. (1) Interincisal angle between the maxillary (U1) and mandibular (L1) central incisor long axes. (2) U1-SN′: angle between U1 long axis and x-axis (horizontal line 7° to SN plane through the S point). (3) U1-PP: angle between the long axis of U1 and PP. (4) L1-MP: angle between the long axis of L1 and mandibular plane. (5) U6-PP: angle between the PP and a line extending along the long axis of the maxillary first molar jig. (6) L6-MP: angle between the MP and a line extending along the long axis of the mandibular first molar jig. (7) U7-PP: angle between the palatal plane and a line extending along the long axis of the mesiobuccal cusp tip and mesiobuccal root apex of maxillary second molar. (8) L7-MP: angle between the MP and a line extending along the long axis of the mesiobuccal cusp tip and mesiobuccal root apex of mandibular second molar. ANS indicates anterior nasal spine; Go, gonion; L1, lower central incisor; L6, lower first permanent molar; Me, Menton; MP, mandibular plane (line passing between Me and Go); N, Nasion; PNS, posterior nasal spine; PP, palatal plane (line passing between ANS and PNS); S, Sella turcica; SN′, horizontal line projecting from SN, 7° clockwise from Sella; SN plane, line passing between S and N; U1, upper central incisor; U6, upper first permanent molar; U7, upper second molar; and L7, lower second molar.

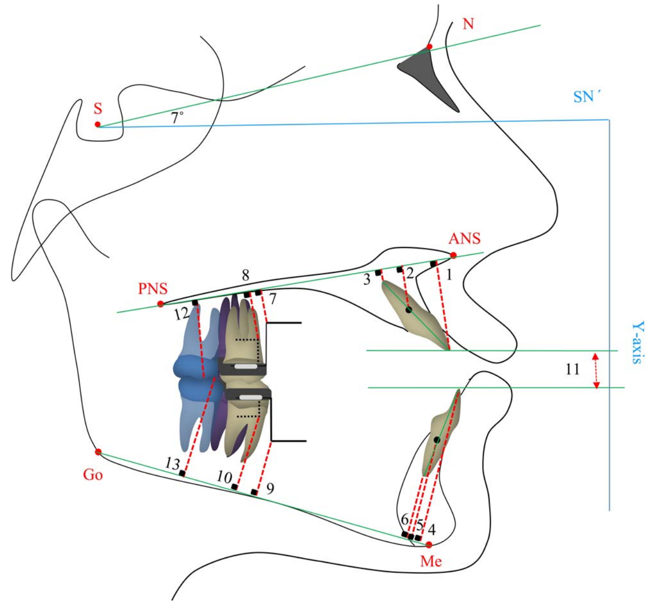

Figure 2. Schematic diagram showing vertical linear dental measurements. The perpendicular distance in mm measured between the PP and the (1) incisal edge, (2) centroid (15 mm from the incisal edge along the long axis of the central incisor for measuring purposes), and (3) apex of U1. The perpendicular distance between the MP and the (4) incisal edge, (5) centroid, and (6) apex of L1. The perpendicular distance between the PP and the maxillary (7) right and (8) left U6 jig. The perpendicular distance between the MP and the mandibular (9) right and (10) left L6 jigs. (11) Overbite (the vertical distance measured between two horizontal lines passing through incisal edges of U1 and L1 perpendicular to the y-axis; vertical plane perpendicular to the x-axis). (12) The perpendicular distance between the PP and the mesiobuccal cusp tip of U7. (13) The perpendicular distance between the MP and the mesiobuccal cusp tip of L7.

Statistical Analysis

Statistical analysis was performed using statistical software (SPSS Inc version 22, IBM Corp, Chicago, IL, USA). After verifying the normality of the data, repeated-measures analysis of variance (RM-ANOVA) was used to compare the data obtained at T1, T2, and T3. Intraexaminer reliability was evaluated using the intraclass correlation coefficient by remeasuring the cephalometric data for 30% of the patients after 3 weeks.

RESULTS

All patients successfully completed the orthodontic treatment. They were all adult women with a mean age of 20.6 years and a mean AOB of 3.05 ± 1.27 mm just before extrusion arches were placed. The average time for open bite closure was 3 months ± 24 days (from T1 to T2), and the average duration of treatment was 1 year and 5 months (from T1 to T3). The intraclass correlation coefficient showed excellent correlation between the test and retest cephalometric measurements (0.93), with a 95% confidence interval of 0.89–0.96.[9] Descriptive statistics and the results of RM-ANOVA for dental and skeletal cephalometric measurements at T1, T2, and T3 are summarized in Tables 1 and 2.

The overbite significantly increased by an average of 4.73 mm ± 1.93 mm from T1 to T2. This was maintained at T3.

Significant maxillary and mandibular incisor extrusion along with significant uprighting of the maxillary and mandibular incisors ($P < .001$) were observed. The vertical and angular measurements between the jigs and PP or MP indicated significant intrusion and mesial tipping ($P < .001$) of the maxillary and mandibular molars.

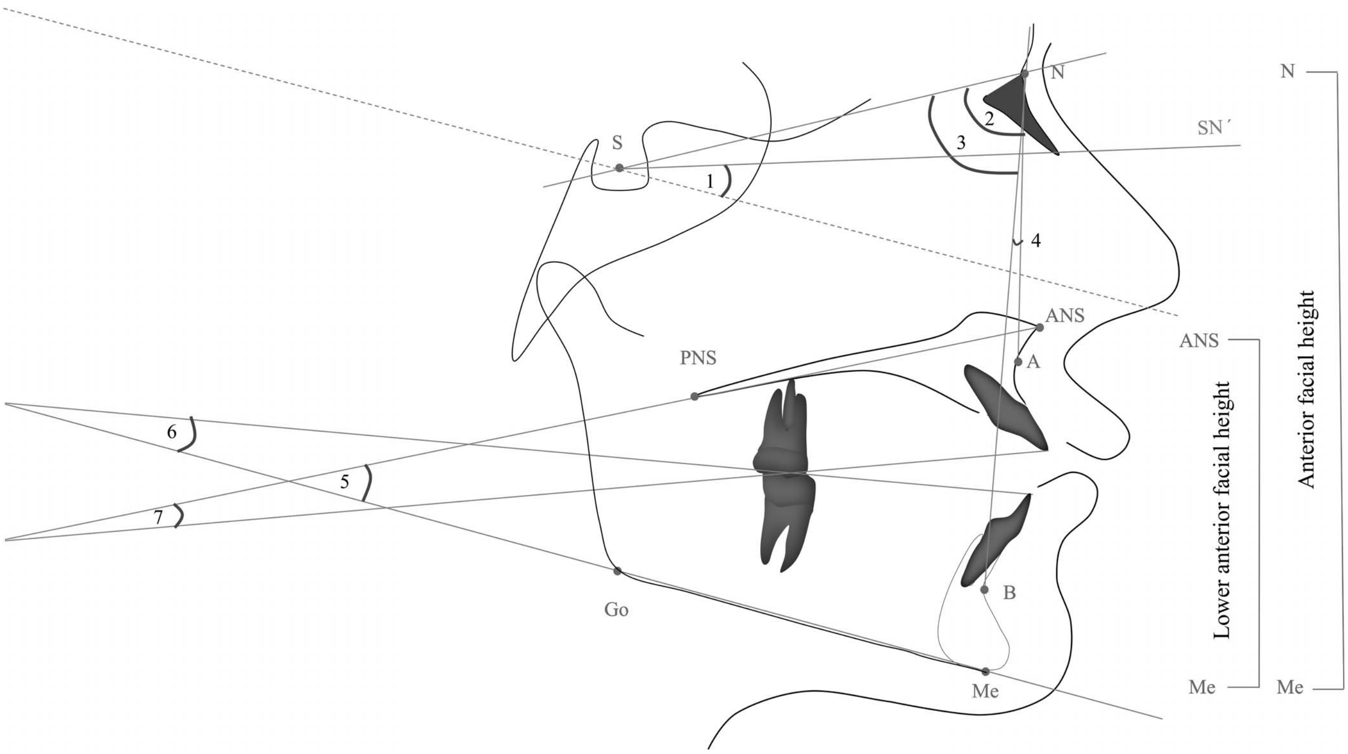

Figure 3. Schematic diagram showing the skeletal linear and angular measurements. (1) Angle between a parallel line to the MP and SN′. (2) SNA (antero-posterior position of the maxillary base in relation to the anterior cranial base). (3) SNB (antero-posterior position of the mandiblular base in relation to the anterior cranial base). (4) ANB (relation between maxillary and mandibular bases). (5) Angle between the PP and MP. (6) Angle between the MP and the lower occlusal plane. (7) Angle between the upper occlusal plane and the PP. (8) Lower anterior facial height: the distance between the ANS and Menton. (9) Total anterior facial height: the distance between N and Menton.

All cephalometric parameters were significantly different between T1 and T2 except for the SNA, SNB, ANB angles. The intrusion of the maxillary and mandibular molars was reflected skeletally by a significant reduction in the SN′-MP and PP-MP angles, the lower anterior facial height, and the total anterior facial height.

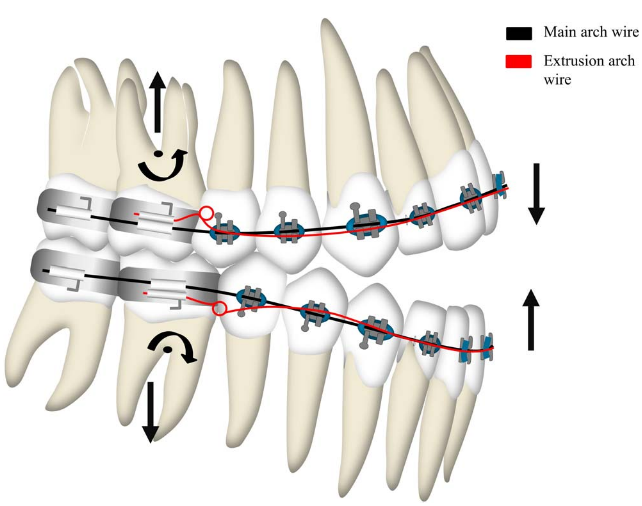

Figure 4. Schematic diagram showing the mechanics of maxillary and mandibular extrusion arches.

All dental and skeletal measurements were stable at T3 compared with the findings at T2, with no statistically significant differences except for a significant change in the angulation of the maxillary and mandibular first molars to the palatal and mandibular planes, respectively.

DISCUSSION

Cephalograms have been extensively used as standard radiographs for evaluating orthodontic treatment in literature.[4] Cone-beam computed tomography can be a more accurate assessment tool for dental measurements without superimpositions in the three planes of space.[10] However, patients would be exposed to more hazardous radiation, which was not justifiable in the current study. The palatal, mandibular, and SN’ planes were used as fixed reference planes because they are not affected by dental movements, hence increasing the reliability of the measurements.[11] Tooth-positioning jigs were used in the study to minimize errors related to the superimposition of right and left molars.

Extrusion arches act by applying a statically determinate one-couple force system in the form of a single extrusive force on the incisors and an intrusive force posteriorly in addition to a mesial crown tipping

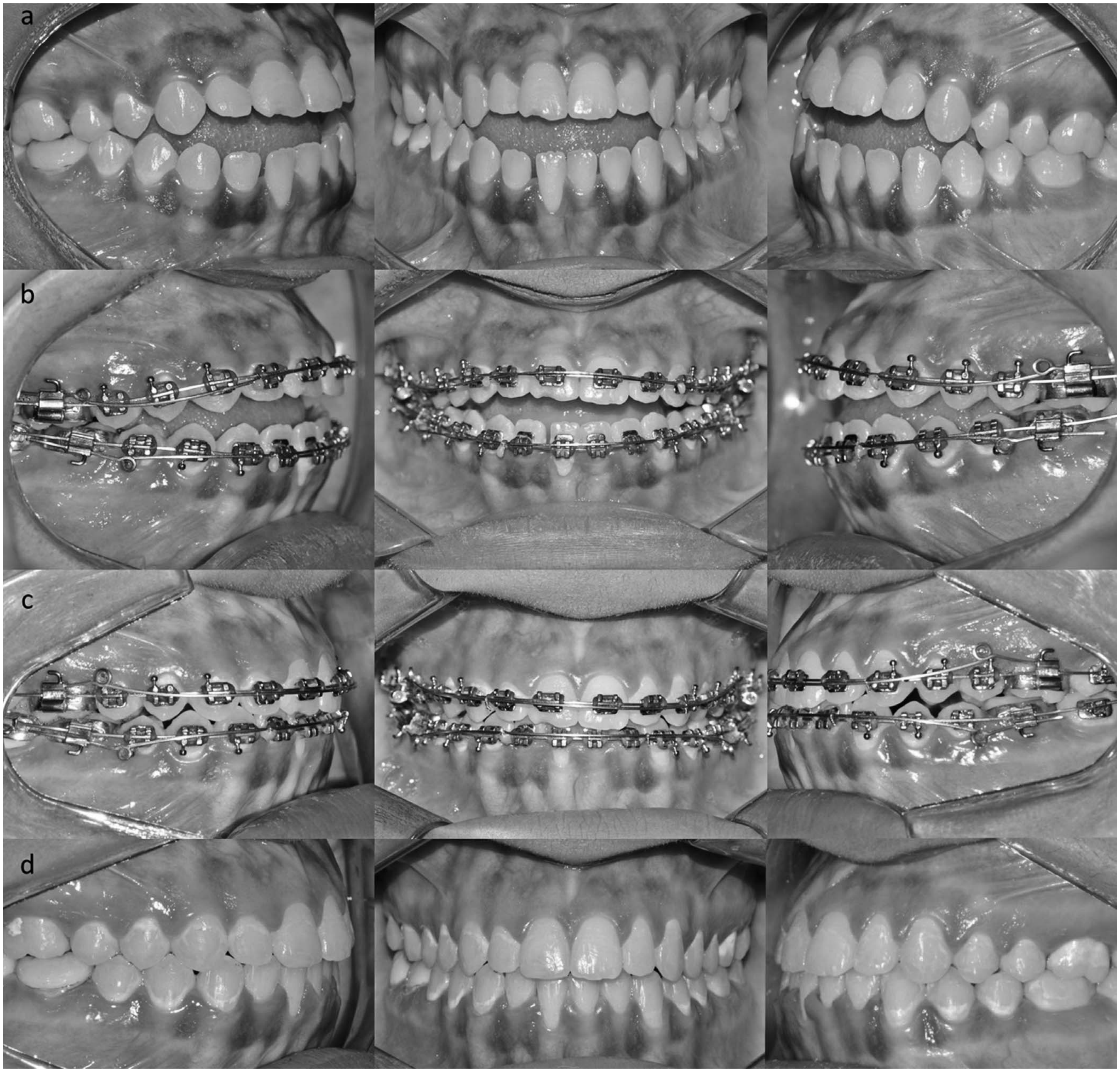

Figure 5. (a) Initial intraoral photographic records of an adult female patient presenting with an AOB. (b) After the alignment phase, with the placement of upper and lower extrusion arches. (c) Two and half months later with the closure of the AOB. (d) At the end of orthodontic treatment.

moment. This approach is most suitable for uncooperative patients with deficient incisal show at rest and smiling.[10] Vertical elastics have been previously used to close AOB by extrusion of the upper and lower incisors.[12]

This study demonstrated that extrusion arches resulted in positive anterior bite closure in 3 months and 24 days (T1 to T2). Previous work reported positive vertical overlap between the upper and lower anterior teeth in 7.79 months when the extrusion arch was employed in the maxillary arch only.[4] The combined mechanics of maxillary and mandibular extrusion arches used in the current study shortened the duration of treatment of AOB because both the upper and lower incisors were extruded, and the upper and lower posterior teeth were intruded. Double extrusion arches uprighted maxillary and mandibular incisors, leading to a significant increase in the interincisal angle by 12.81°, in agreement with previous studies.[4,13] The positive overlap was maintained at T3, in agreement with other studies investigating different mechanics in the treatment of AOB.[14,15]

Table 1. Mean and SD of Cephalometric Dental Variables at T1, T2, and T3

Variable	T1 Mean	T1 SD	T2 Mean	T2 SD	T3 Mean	T3 SD
U1-PP (°)	121.55[a]	5.66	115.18[b]	4.79	116.68[b]	4.32
U1-SN′ (°)	120.09[a]	6.32	114.18[b]	5.60	115.18[b]	5.71
Interincisal angle (°)	110.55[a]	8.73	123.36[b]	8.08	122.72[b]	8.22
U1 incisal edge-PP (mm)	27.18[a]	2.99	29.23[b]	3.13	28.77[b]	3.31
U1 centroid-PP (mm)	13.86[a]	3.32	15.77[b]	3.34	15.45[b]	3.10
U1 apex-PP (mm)	6.18[a]	2.86	8.09[b]	2.77	8.45[b]	2.88
L1-MP angle (°)	96.27[a]	7.24	87.82[b]	5.12	88.54[b]	4.98
L1 incisal edge-MP (mm)	38.55[a]	2.21	41.09[b]	2.91	40.81[b]	2.75
L1 centroid-MP (mm)	24.09[a]	3.96	26.18[b]	3.92	25.86[b]	3.72
L1 apex-MP (mm)	20.27[a]	2.00	22.50[b]	2.25	22.27[b]	2.11
Right U6-PP (mm)	12.90[a]	4.76	11.95[b]	4.61	11.77[b]	4.49
Left U6-PP (mm)	12.68[a]	4.01	11.68[b]	4.17	11.36[b]	4.08
Right U6-PP (°)	88.73[a]	11.22	93.36[b]	11.41	91.45[c]	11.26
Left U6-PP (°)	88.91[a]	9.27	93.81[b]	9.14	91.91[c]	9.12
Right L6-MP (mm)	23.09[a]	4.24	22.27[b]	4.38	22.05[b]	4.39
Left L6-MP (mm)	22.89[a]	3.72	21.5[b]	3.69	21.13[b]	4.09
Right L6-MP (°)	74.64[a]	6.95	79.45[b]	6.88	75.64[a]	7.23
Left L6-MP (°)	74.09[a]	7.96	78.27[b]	8.34	75.23[a]	7.82
U7-PP (mm)	18.9[a]	2.3	18.23[a]	3.4	18.12[a]	2.8
U7-PP (°)	81.32[a]	4.3	80.29[a]	3.8	81.46[a]	3.05
L7-MP (mm)	28.12[a]	3.97	27.82[a]	2.87	27.1[a]	3.33
L7-MP (°)	79.23[a]	2.21	79.11[a]	3.87	78.23[a]	4.02
Overbite (mm)	−3.05[a]	1.27	1.68[b]	0.66	1.41[b]	0.59

[a-c] The same lowercase letters in the same row indicate no significant difference between groups.

In AOB treatment, it is essential to intrude molars or at least avoid molar extrusion to prevent any possible interference with bite closure and a subsequent increase in AFH and LAFH.[16] Previous studies reported a significant increase in MP angle, AFH, and opening mandibular rotation when anterior elastics and curved archwires or a multiloop edgewise archwire technique was implemented.[14,17,18]

Upper first molars were intruded to a greater extent than were lower molars despite both experiencing the same force for intrusion exerted by the extrusion arch. The law of equilibrium dictates that the intrusive force on the molars is equal and oppositely directed to the extrusive force on the incisors. This difference in expression could be attributed to differences in the bone in the upper and lower jaws. The spongy nature of the bone of the maxillary arch might allow for a faster bone resorption-bone deposition process compared with the denser compact bone in the mandible.[19]

Significant mesial tipping of the upper and lower molars resulted from the moment produced by extrusion arch mechanics on the posterior segments.[2,3] Previous work reported an increase in mesial tipping of the upper molar by 11.49°.[4] In that study, a maxillary extrusion arch was used for an average of 7.79 months in young patients with less mature bone. In contrast, in the current study, extrusion arches were applied for a shorter duration (3.8 months) and led to fewer adverse effects on the molars. Also, the presence of spacing between the teeth in the mixed dentition might have allowed more mesial inclination of the molars in the previous study. In the current study, the extrusion arch

Table 2. Mean and SD of Cephalometric Skeletal Variables at T1, T2, and T3

Variable[a]	T1 Mean	T1 SD	T2 Mean	T2 SD	T3 Mean	T3 SD
SNA (°)	80.63[b]	2.51	80.81[b]	2.62	80.91[b]	2.59
SNB (°)	77.86[b]	3.36	78.14[b]	3.51	78.59[b]	3.9
ANB (°)	2.68[b]	2.64	2.59[b]	1.55	2.18[b]	1.79
SN′-MP (°)	31.32[b]	3.84	30.50[c]	3.72	29.73[c]	4.01
AFH (mm)	115.63[b]	4.18	114.64[c]	4.03	114.55[c]	4.29
LAFH (mm)	67.05[b]	4.30	66.05[c]	4.62	63.55[c]	4.55
PP-upper occlusal plane (°)	9.05[b]	4.07	11.27[c]	4.45	10.81[c]	3.84
MP-lower occlusal plane (°)	18.55[b]	4.20	21.23[c]	4.02	21.14[c]	4.35
PP-MP (°)	29.86[b]	6.24	29.09[c]	6.41	28.81[c]	6.06

[a] AFH indicates anterior facial height; LAFH, lower anterior facial height.
[b,c] The same lowercase letters in the same row indicate no significant difference between groups.

was ligated over a base archwire engaging all of the teeth with no spaces between them. Other studies reported that the magnitude of tooth displacement was inversely proportional to the age of the participants.[20] In addition, in the current study, a transpalatal arch was used as stabilizing anchorage along with the continuous base archwire to dissipate forces over as many teeth as possible. Continued leveling with heavy wires and vertical elastics after the extrusion arches were removed led to significant uprighting of the mesially tipped maxillary and mandibular first molars at T3.

The use of two occlusal planes (upper occlusal plane and lower occlusal plane) was adopted in this study to provide more accurate measurements than the use of one occlusal plane because patients with AOB usually present with two separate occlusal planes as observed by Nahoum.[21] The PP-upper occlusal and MP-lower occlusal angles increased significantly from T1-T2, indicating clockwise rotation of the upper occlusal plane and counterclockwise rotation of the lower occlusal plane attributed to the extrusion of incisors and the intrusion of molars, ultimately bringing the two occlusal planes toward each other to close the bite.

One limitation of the current study could have been the use of two-dimensional lateral cephalometry and its related errors in magnification, landmark identification, superimposition, and unavoidable projection error. However, all the lateral cephalograms were taken with the same cephalostat and machine and with the same standardized settings to ensure the consistency of the imaging-related magnification factors. In addition, tooth-positioning jigs were employed to minimize errors related to the superimposition of the right and left molars. Further studies should be conducted to investigate the long-term effects and posttreatment stability of this treatment technique and its effects on root resorption and periodontal condition.

CONCLUSIONS

- Combined use of maxillary and mandibular extrusion arches resulted in significant dental and minor skeletal changes that led to the correction of the AOB.

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