Posterior crossbite with mandibular asymmetry treated with lingual appliances, maxillary skeletal expanders, and alveolar bone miniscrews

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Posterior crossbite and mandibular asymmetry affect esthetics and function. We report treatment of 3 patients with posterior crossbite with mandibular asymmetry but different anteroposterior and vertical characteristics. Treatment methods included maxillary skeletal expander, miniscrews, and lingual appliances. The results show that by using these appliances, ideal transverse, anteroposterior, and vertical control is possible in patients who have concerns about the esthetics of buccal appliances. Lingual appliances can provide satisfying results when combined with a maxillary skeletal expander and miniscrews in complex patients. (Am J Orthod Dentofacial Orthop 2021;■:■-■)

Posterior crossbite is one of the most prevalent malocclusions, occurring in 5% to 15% of the general population and causing functional and esthetic problems.[1,2] Mandibular shift often occurs, affecting masticatory function and the condyle-fossa relationship.[2,3] Patients with posterior crossbite often experience muscle tenderness, headache, and temporomandibular joint problems.[4,5] Previous studies have reported that correction of posterior crossbite by maxillary expansion enlarges the nasal volume, lowers the palate, and reduces nasal resistance, resulting in improved nasal breathing.[6-8] A recent study indicated that surgically-assisted rapid maxillary expansion (SARME) resulted in a significant improvement in nasal breathing and sleep quality.[9]

One of the most difficult malocclusions to treat is the high-angle posterior crossbite. A conventional approach using a hyrax expander tends to tip the molars buccally, causing the lingual cusp to extrude, worsening the high-angle tendency.[10] A recent development is the maxillary skeletal expander (MSE),[11-13] a form of microimplant assisted rapid palatal expansion (MARPE)[14] characterized by the presence of 4 mini-implants placed in the posterior portion of the palate with bicortical engagement. This method has been effectively used in patients with posterior crossbite and mandibular asymmetry, similar to our patients.[11,15] One of the suggested advantages of the MSE is that it enables parallel expansion, resulting in less tipping of the molars than occurs with a conventional expander.[16-18] Thus, MSE should be especially suitable for high-angle patients. In addition, MSE has a substantial effect on the nasal volume and, as a result, improves airway and nose breathing.[19,20]

Another effective device to control vertical dimension is the use of miniscrews. Miniscrews have been used to correct an open bite in patients and occlusal cant in the past.[21,22] Miniscrews are effective not only for vertical control but also for the anteroposterior (AP) control, particularly in patients involving asymmetric space closure to correct a midline deviation.[23,24] Thus, the combined use of MSE and miniscrews should provide a favorable outcome in controlling transverse, vertical, and AP dimensions.

Many adult patients, especially in Asian populations, undertake orthodontic treatment for esthetic reasons.

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Fig 1. Patient 1: pretreatment facial and intraoral photographs.

Recently, aligner therapy has been widely used because of its superior esthetics; however, there are limitations in its function when compared with conventional braces.[25,26] In contrast, lingual appliances are known to be as effective as conventional braces.[27,28] Therefore, lingual appliances should be the treatment of choice for patients who are hesitant to start orthodontic treatment because of esthetic concerns.

Here we report on 3 patients with posterior crossbite with high angle and asymmetry successfully treated with MSE combined with a lingual appliance.

PATIENT 1

A 15-year-old female visited our orthodontic clinic with chief complaints of an inability to bite with her front teeth and reduced exposure of her maxillary teeth while smiling. Facial photographs indicated a convex profile with a retruded mandible, a mandibular shift to the left, an obtuse nasolabial angle, and a decreased exposure of the maxillary incisors while smiling (Fig 1). Intraoral photographs revealed a bilateral posterior crossbite with anterior open bite (Fig 1). Her occlusion was Class II in the canine and molars, with a narrow V-shaped maxillary arch and a mandibular midline shift to the left. Cephalometric analysis indicated a skeletal Class II (SNA, 84°; SNB, 77°; ANB, 7°) pattern with a high-angle tendency (FMA 35°) and Wits appraisal of 5 mm (Fig 2; Table I). The posteroanterior (PA) radiographs showed that the mandibular midline was shifted to the left (Fig 2).

The following treatment objectives were established: (1) correct the posterior crossbite and anterior open bite, (2) establish an ideal overbite and overjet, (3) achieve Class I canine and Class II molar relationship, (4) improve the mandibular asymmetry, and (5) improve the facial profile.

The first treatment option was to perform a double-jaw surgery to correct the AP and vertical discrepancies. Surgically-assisted maxillary expansion and a LeFort I osteotomy with mandibular advancement were planned. The second option was a nonsurgical approach involving the use of MSE to expand the maxilla, followed by extraction of the maxillary second premolars to correct AP discrepancy and the use of miniscrews to control the vertical dimension. Because the patient will continue to grow and would prefer to avoid surgery, we decided on the second option.

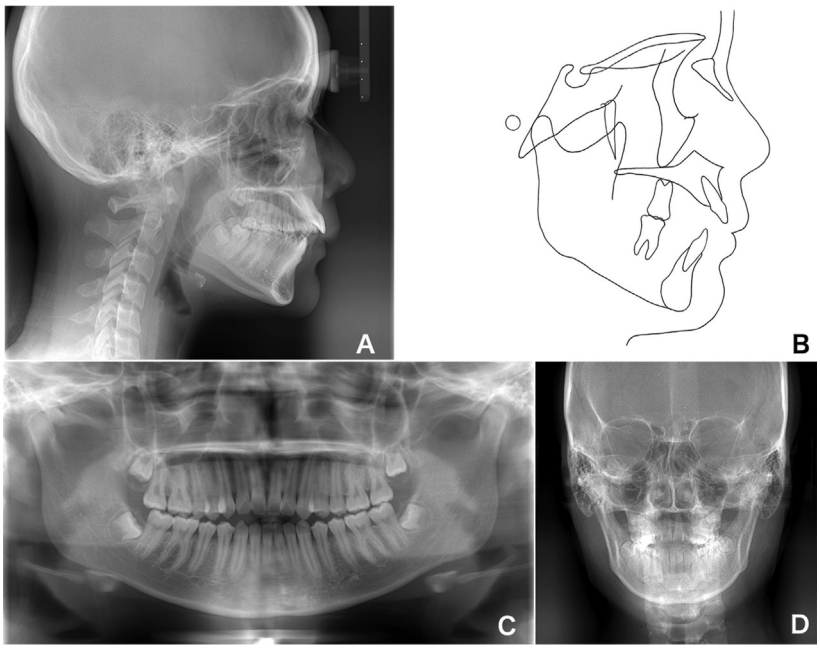


Fig 2. Patient 1: **A,** pretreatment cephalometric radiograph; **B,** cephalometric tracing; **C,** panoramic radiograph; **D,** PA radiograph.

Table I. Patient 1: cephalometric values

XXX	*Pretreatment, 15 y 8 mo*	*Posttreatment, 18 y 4 mo*
SNA	84.0°	83.5°
SNB	77.0°	78.0°
ANB	7.0°	5.5°
Facial angle	86.0°	87.0°
y-axis	64.0°	63.0°
FMA	25.0°	23.5°
Mandibular plane to SN	35.0°	33.5°
Occlusal plane to SN	28.5°	23.5°
U1 to SN	107.0°	96.0°
IMPA (L1 to MP)	91.0°	95.5°
FMIA	64.0°	61.0°
Interincisal angle	125.0°	133.0°
U1 to A-Pog	9.0 mm	5.5 mm
L1 to A-Pog	−1.0 mm	3.0 mm
AO-BO	−0.5 mm	1.0 mm
E-line: upper	0 mm	−2.0 mm
E-line: lower	−2.0 mm	−1.0 mm
Overjet	9.0 mm	3.0 mm
Overbite	−4.0 mm	3.0 mm

We first placed the MSE and confirmed that the screws were placed bicortically using cone-beam computed tomography (CBCT). Bicortical placement of the screws (at least 1-2 mm into the nasal cavity) is important for preventing a triangular pattern of expansion which minimizes the unwanted strain to the maxillary alveolar bone (Fig 3). The jackscrew was activated once in the morning and once at night (twice a day) every 3 days for the first 3 weeks and once every 3 days for another 3 weeks (a total of 4.2 mm of expansion). In the maxillary arch, lingual appliances with 0.018-in bracket slots (incisors and canines: sella turcica bridging [Ormco, Glendora, Calif]; premolars and molars: Clippy [Tomy, Tokyo, Japan]) were bonded using an indirect setup with specific torque and angulation prescriptions (Fig 4). In the mandibular arch, labial appliances with 0.018-in bracket slots were bonded because the patient had a large tongue and did not want any interference with tongue movement. After successful expansion, we extracted the maxillary second premolars instead of the first premolars because of the dental morphology (Fig 5). The same MSE was used as anchorage to retract the maxillary first premolars. During the first premolar retraction, the arms of MSE were cut, and the MSE, serving as skeletal retention, was removed approximately 6 months after completing the expansion (Fig 5). After leveling, 2 miniscrews (Proceed, Tokyo, Japan; Dual-top Auto Screw; diameter, 1.3 mm; length, 6 mm) were placed buccally between maxillary first molars and first premolars, and the intrusion of the molars was commenced (Fig 5).

The appliances were removed 32 months after the initiation of the treatment, and maxillary and mandibular lingually bonded retainers were placed. Full Class

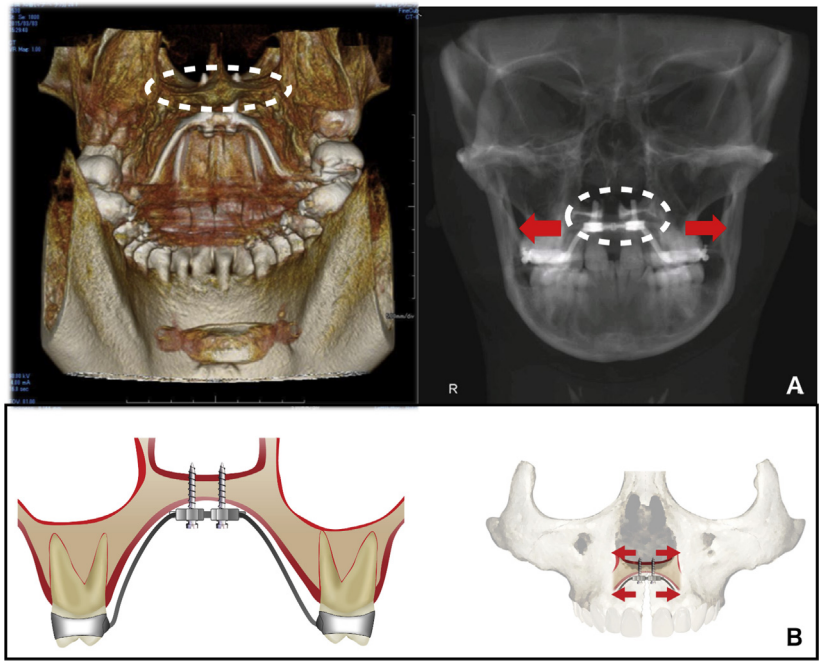
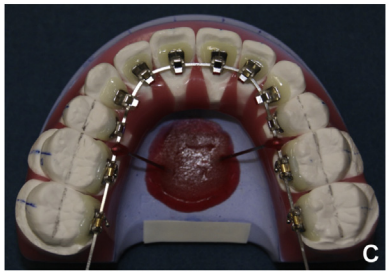


Fig 3. Patient 1: **A,** CBCT image showing placement of MSE. Bicortical engagement (*dotted circle*) of the miniscrews is essential in nonsurgical midfacial expansion; **B,** maxillary expansion with bicortical engagement MSE. Generally, an average of 2 mm soft tissue, 5-6 mm of bone contact, 2 mm of screw head contact, and a total of 9-11 mm of miniscrews are required for the force to be expressed in a parallel direction (*red*) with less strain.

Actual	3	2	UR1	UL 1	2	3
Torque	+4°	+5°	+10°	+10°	+5°	+4°
Tip	+8°	+6°	+4°	+4°	+6°	+8°

Added	3	2	UR1	UL 1	2	3
Torque	0°	+2°	+6°	+6°	+2°	0°
Tip	+5°	+5°	+4°	+4°	+5°	+5°

A



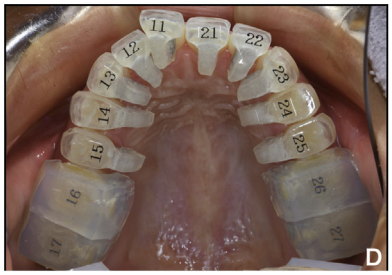


Fig 4. Patient 1: an indirect method for a lingual appliance. **A,** Changes made for the lingual bracket prescription showing the actual initial torque and the amount of torque added to the bracket; **B,** final setup model from the buccal; **C,** occlusal views; **D,** patient indirect tray for placement of the lingual brackets.

II molar and Class I canine relationships with ideal overjet and overbite were achieved (Fig 6). The posterior crossbite was successfully corrected by skeletal expansion at the maxillary suture with MSE. The anterior open bite was corrected mainly by incisor extrusion during the retraction. The large overjet and midline

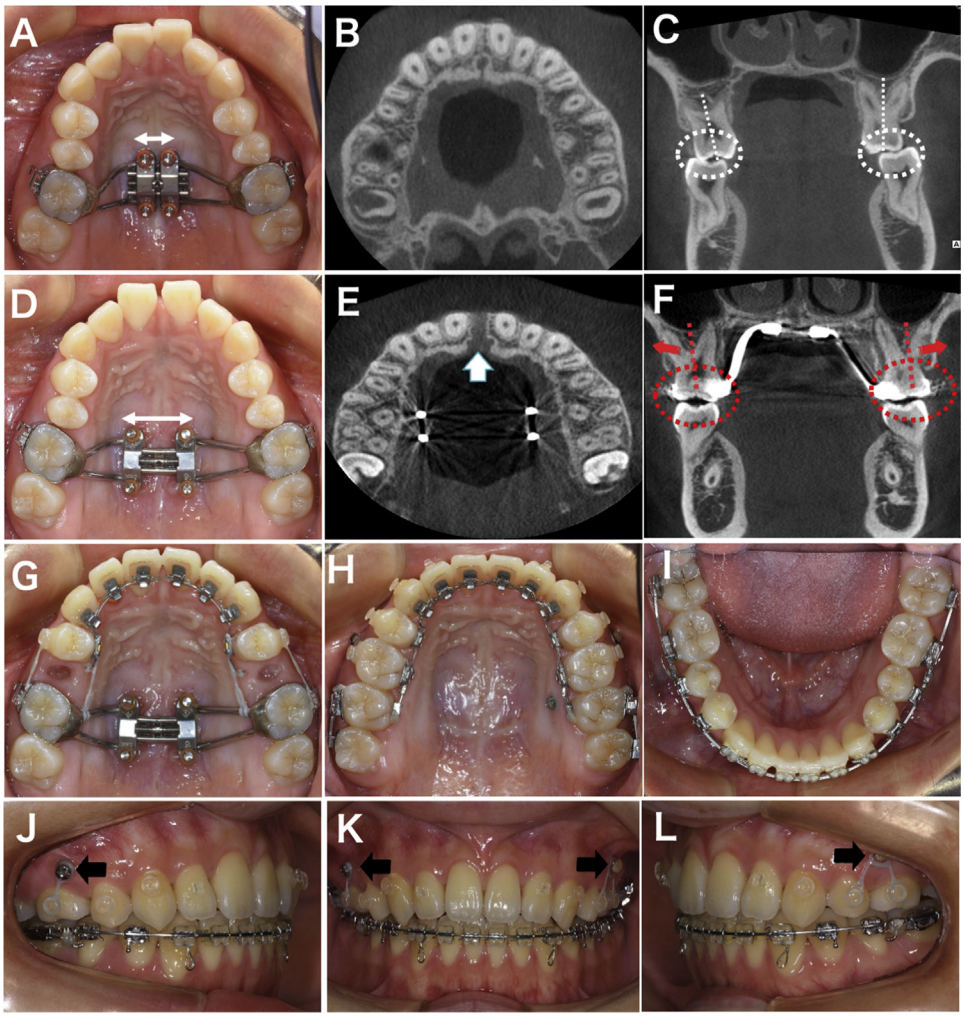


Fig 5. Patient 1: photographs and CBCT images of maxillary skeletal expansion. **A-C,** Before expansion the preactivated screws (**A,** *arrow*; **B** and **C**, CBCT coronal and sagittal images showing molar tipping with a crossbite; **C,** *dotted circle and lines*); **D-F,** after expansion photograph, coronal CBCT (**E,** *arrow*) and sagittal CBCT images (**F,** *red*, direction of expansion; *red*, change in molar angulation); **G,** intraoral photographs of the initial stage of retracting the premolars using the MSE as anchorage; **H** and **I**, after retraction of the maxilla and the mandible; **J-L,** miniscrews were used to control the vertical dimension in the maxillary molars (*black*).

deviation were also improved by extraction of the second premolars and subsequent retraction of the anterior segment using the MSE as anchorage. The cephalometric analysis indicated that ANB decreased by 1.5°, Wits appraisal decreased by 4 mm, and FMA decreased by 1.5°, with a counterclockwise rotation (Figs 7 and 8; Table I). The distance from the E-line to upper lips and E-line to the lower lips decreased by 2 mm and increased by 1 mm, respectively, resulting in less upper lip protrusion. The retraction and extrusion of maxillary incisors also improved the incisor display when smiling (Figs 6 and 8). The PA cephalometric analysis revealed an improvement in the midline discrepancy. In addition, the correction of the midline might be due to the correction of the existing functional shift before the pretreatment has been resolved. This could be confirmed from the lateral cephalometric radiographs that indicate a double mandibular plane initially and a single mandibular plane at the end (Figs 2 and 7). The cant of the maxillary occlusal plane also improved from −1.3 mm to −0.6 mm, and the maxillary width increased from 69.1 mm to 73.7 mm (Fig 8).

Fig 6. Patient 1: posttreatment facial and intraoral photographs.

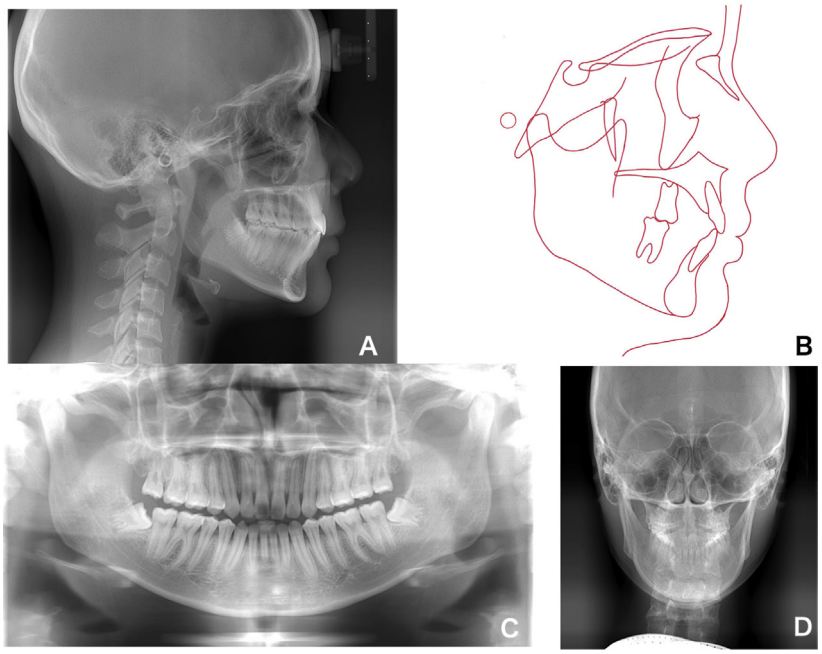


Fig 7. Patient 1: **A-D,** posttreatment cephalometric radiograph, cephalometric tracing, and panoramic and PA radiographs.

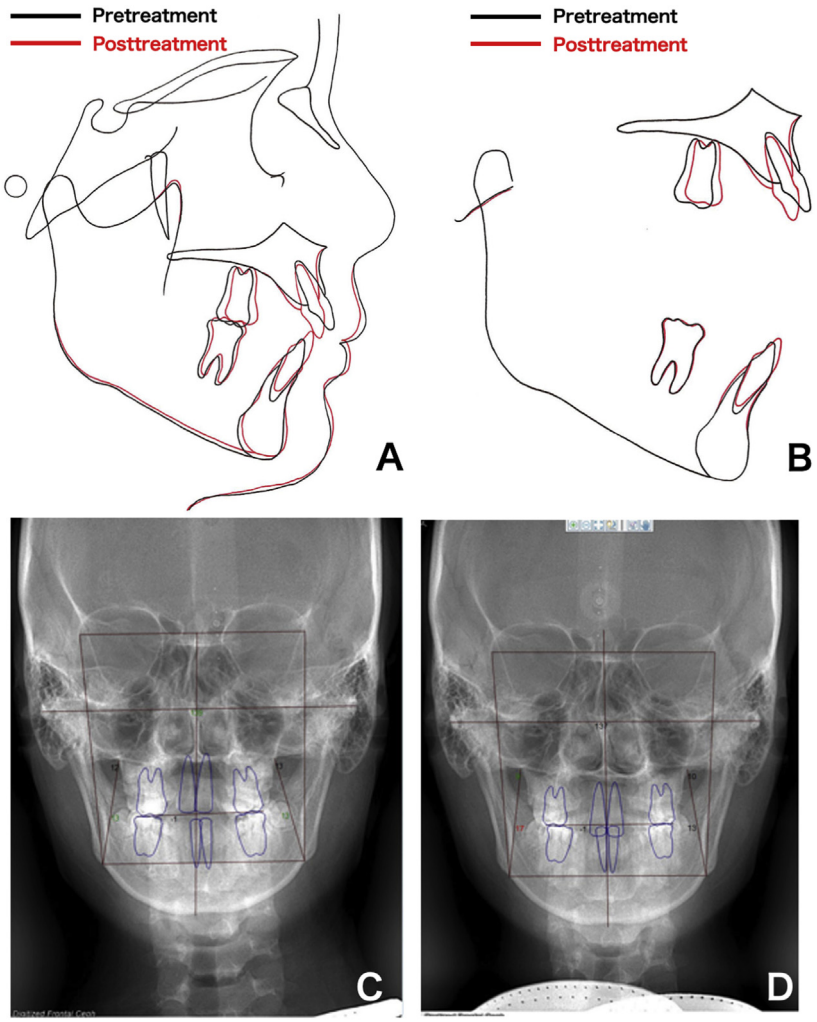


Fig 8. Patient 1: **A** and **B,** pretreatment and posttreatment cranial and regional superimpositions; **C** and **D,** pretreatment and posttreatment PA radiographs. Correction of the midline deviation is indicated in the PA radiograph.

PATIENT 2

A 26-year-old woman visited our orthodontic clinic with chief complaints of discomfort on biting and space on the left side of the occlusion. Facial photographs indicated a bimaxillary protrusive profile with retruded chin (Fig 9). Midline deviation to the left of the mandible was observed on the frontal facial photograph. The intraoral photographs revealed that the mandibular arch was positioned to the left with a crossbite from the left canine to the first molar (Fig 9). The molar relationships were Class I on the right and Class II on the left buccal segments. The maxilla and mandible both had V-shaped arch forms, and some spaces were observed. Cephalometric analysis indicated a skeletal Class II (SNA, 80°; SNB, 75°; ANB, 5°) relationship and a hyperdivergent pattern (FMA, 39°), and a Wits appraisal of −2.0 mm (Table II). A difference in the length of the right and mandibular left rami was evident from the panoramic radiograph, and the PA cephalometric radiograph, together with the photographs, revealed that the maxillary and mandibular dental midlines were both shifted to the right of the facial midline and the maxillary occlusal plane was canted (Fig 10).

The following treatment objectives were established: (1) correct the posterior left crossbite, (2) close all spaces, (3) achieve a Class I molar relationship, (4) improve the maxillary and mandibular midline discrepancy, and (5) improve the facial profile.

The first treatment option was to perform 1-jaw mandibular advancement surgery on the left side to

Fig 9. Patient 2: pretreatment facial and intraoral photographs.

Table II. Patient 2: cephalometric values

XXX	*Pretretment, 26 y 9 mo*	*Posttreatment, 29 y 4 mo*
SNA	80°	80°
SNB	75°	75.5°
ANB	5°	4.5°
Facial angle	82.5°	83°
Y-axis	69.5°	70°
FMA	39°	37°
Mp-SN	45°	44°
Occlusal plane to SN	25°	26°
U1 to SN	98°	92°
IMPA (L1 to MP)	89°	84°
FMIA	52°	59°
Interincisal angle	128°	139°
U1 to A-Pog	7.5 mm	4.5 mm
L1 to A-Pog	3.5 mm	1.0 mm
E-line: upper	4.5 mm	2.0 mm
E-line: lower	6.0 mm	1.0 mm
Overjet	4.0 mm	3.0 mm
Overbite	2.5 mm	3.0 mm

correct the mandibular asymmetry with maxillary rapid palatal expansion. The second option was a nonsurgical approach involving the use of MSE to expand the maxilla and miniscrews to control the AP and vertical dimensions. Because the patient wanted to avoid surgery, we decided to proceed with the second option.

The MSE was placed, and the jackscrew was activated twice a day for the first 3 weeks until a diastema was confirmed and then activated once a day for an additional 3 days (a total of 9.0 mm of expansion). During the expansion, buccal brackets were placed on the right first and second molars and clear lingual buttons on the first and second premolar, and cross elastics and short Class III elastics were used for 3 months to prevent overexpansion on the right side. After confirmation of skeletal expansion, lingual appliances with 0.018-in bracket slots (incisors and canines: sella turcica bridging [Ormco]; premolars and molars: Clippy [Tomy]) were bonded, and leveling of the maxillary arch and closing of the diastema was initiated, followed by leveling of the mandibular arch (Fig 11). After the initial leveling, 2 miniscrews each in the palate and the mandibular buccal region for the AP and vertical control. The right palatal miniscrew was used to intrude the maxillary right molar for the cant correction, the left palatal miniscrew was used to distalize the left segment for the Class II correction, the mandibular right miniscrew was used to shift the lower midline to the right, and the mandibular left miniscrew was used to slightly mesialize left premolar for the midline correction (Fig 12).

Total treatment time was 31 months, after which maxillary and mandibular lingually bonded retainers

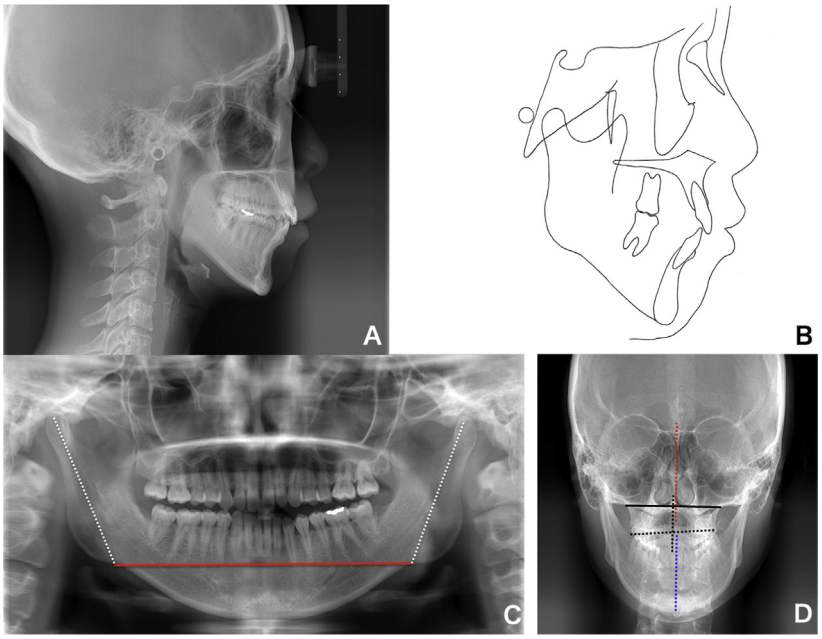


Fig 10. Patient 2: **A-D,** pretreatment cephalometric radiograph, cephalometric tracing, panoramic and PA radiographs. A substantial difference in the length of the condyle is observed (*white* in **C**). The cant of the occlusal plane (*black* in **D**) and the midline deviation of the mandible (*blue* in **D**) are also observed in the PA radiograph.

were placed. The facial profile and incisor display when smiling were greatly improved compared with the pretreatment photographs (Fig 13). Class I molar and canine relationships were achieved with an ideal overjet and overbite. The posterior crossbite on the left was successfully corrected by the skeletal expansion of the maxillary suture with MSE. The midline deviation and the occlusal cant were corrected by a directional force system with miniscrews. The correction of the maxillary occlusal plane promoted a mandibular shift to the center and improved the mandibular position. The cephalometric analysis shows that ANB decreased by 1.5° and FMA decreased from 39° to 37°, indicating a counterclockwise rotation of the mandible (Figs 14 and 15; Table II). The upper lip was retracted from 4 mm to 2 mm, and the lower lip was retracted from 6 mm to 1.5 mm, relative to the E-line. The PA radiograph analysis shows that the occlusal plane was leveled from −2.0 to −0.5, correcting the mandibular asymmetry (Fig 15).

PATIENT 3

A 21-year-old man visited our orthodontic clinic with chief complaints of crowding and mandibular protrusion. Facial photographs indicated a concave profile with decreased maxillary incisor display when smiling (Fig 16). The intraoral photographs show Class III molar and canine relationships with a bilateral posterior crossbite (Fig 16). There was moderate crowding in maxillary and mandibular arches, with a V-shaped maxilla and a narrow mandible with lingually tipped molars. The anterior teeth were in an edge-to-edge relationship with the maxillary lateral incisors in crossbite. Cephalometric analysis indicated a skeletal Class III (SNA, 78°; SNB, 84°; ANB, −6°) pattern with a high angle (FMA, 31°) (Table III). A difference in the length of the right and mandibular left rami was evident from the panoramic radiograph. The PA radiograph and photographs revealed both dental midlines were shifted to the right of the facial midline; however, the mandibular skeletal midline was shifted to the left (Fig 17). A cant of the maxillary occlusal plane was also evident in the PA radiograph.

The following treatment objectives were established: (1) correct the anterior and posterior crossbites, (2) achieve an ideal overjet and overbite, (3) achieve a Class I relationship, (4) improve the midline discrepancy, and (5) improve the facial profile.

The first treatment option was to perform double-jaw surgery with maxillary advancement and mandibular bilateral sagittal setback. The second option was a nonsurgical approach involving MSE for maxillary

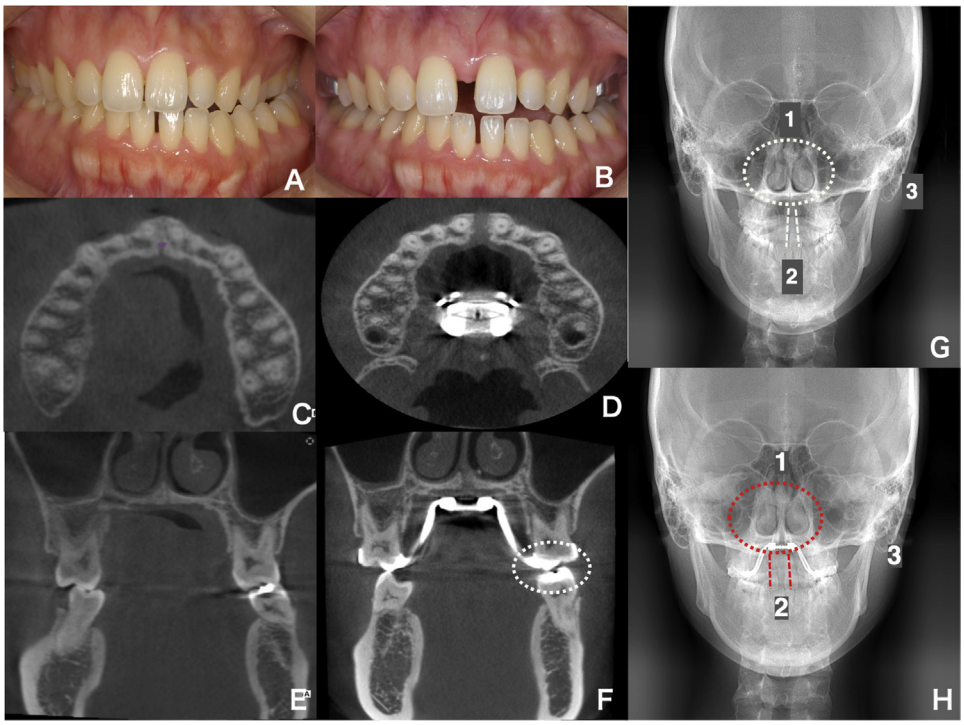


Fig 11. Patient 2: **A** and **B,** intraoral photographs before and after the maxillary skeletal expansion; **C** and **D,** cross-sectional CBCT images before and after expansion; **E** and **F,** sagittal CBCT view before and after expansion. Correction of the crossbite at the first molar is indicated (*white* in **F**); **G** and **H,** PA radiograph before and after expansion. Notice the changes in the nasal cavity (**1**, *dotted circle*), maxillary central incisor angulation (**2**, *dotted line*), and the shape of the maxilla **(3)**.

Fig 12. Patient 2: intraoral photographs showing the 3-dimensional control by miniscrews. Palatal right miniscrew (*white*) is intruding the maxillary right molars to correct the cant of the occlusal plane; the left palatal miniscrew (*black*) is distalizing the maxillary left side; the mandibular right buccal miniscrew (*green*) is distalizing the right segment; the mandibular left buccal miniscrew (*yellow*) is intruding while mesializing the left segment to correct the midline deviation.

expansion, a facemask for maxillary protraction, and miniscrews to control the AP dimension (distalization of the mandibular molars) and the vertical dimension (prevention of the molar extrusion). Because the patient wanted to avoid surgery, we decided to proceed with the second option.

Fig 13. Patient 2: posttreatment facial and intraoral photographs.

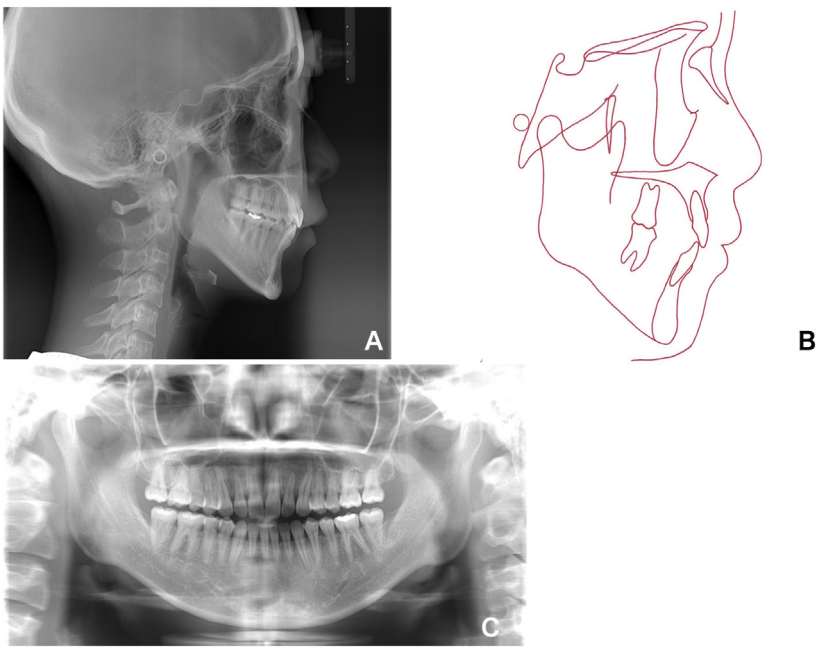


Fig 14. Patient 2: **A-C,** posttreatment cephalometric radiograph, cephalometric tracing, and panoramic radiograph.

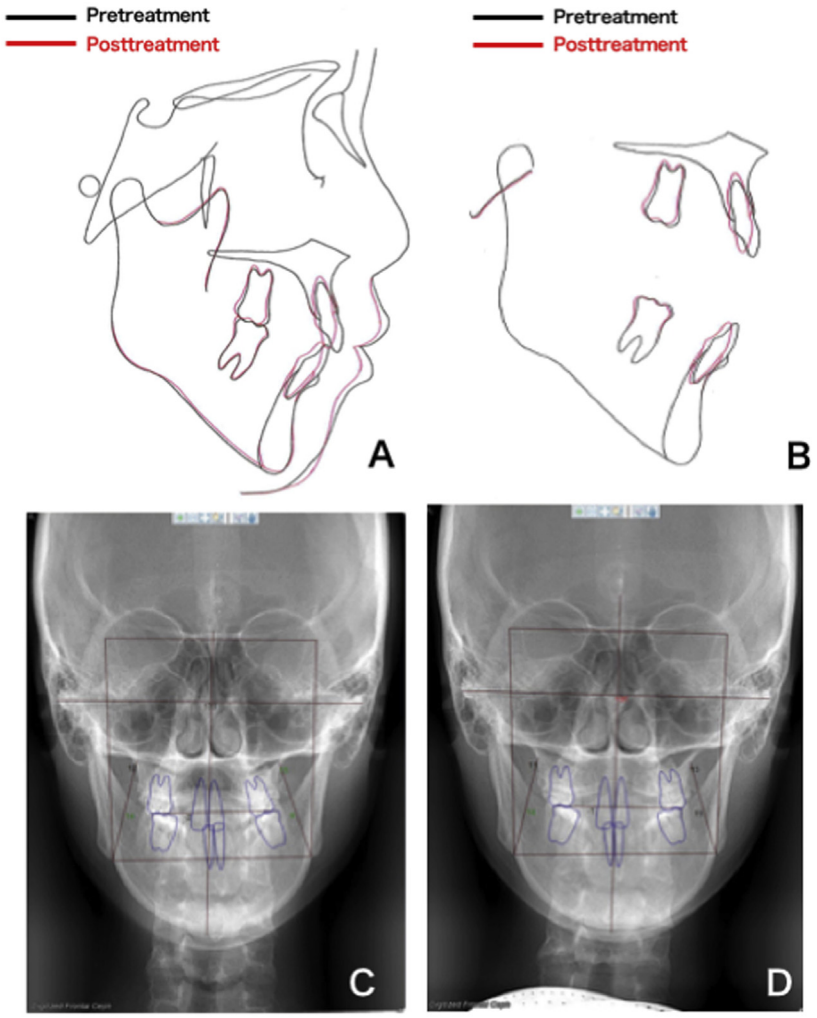


Fig 15. Patient 2: **A** and **B,** pretreatment and posttreatment cranial and regional superimpositions; **C** and **D,** pretreatment and posttreatment PA radiographs. Correction of the midline deviation is indicated in the PA radiograph.

We inserted MSE with hooks for a facemask, and the jackscrew was activated twice a day for the first 2 weeks and once a day for another 2 weeks (total of 8.4 mm of expansion). The facemask was used for 10 hr/d for 8 months (500 g of protraction force per side). In the maxillary arch, lingual appliances with 0.018-in bracket slots (incisors and canine, Kurtz seventh-generation [Ormco]; molars, Clippy [Tomy]) were bonded using an indirect setup with specific torque and angulation prescriptions (Fig 18). In the mandibular arch, labial appliances with 0.018-in bracket slots were bonded because a distalization of the entire arch was planned with miniscrews, and labial appliances would offer more convenient access and biomechanically more favorable. Furthermore, the patient had a narrow mandibular arch, and the tongue would be in constant contact with a lingual appliance, causing unwanted irritation; therefore, the labial appliance was chosen for the mandible. After the leveling, miniscrews (Dual-top Auto Screw, ProSeed Corp, Seoul, South Korea; diameter, 1.6 mm; length, 6.0 mm) were placed between the mandibular first and second molars (Fig 18). After 12 months, a positive overjet was achieved by using facemasks against the bone-borne MSE and the distalization of the mandibular arch (Fig 18).

Total treatment time was 30 months, after which bonded maxillary and mandibular lingual retainers were placed. Class I molar and canine relationships were achieved with ideal overjet and overbite (Fig 19). The anterior and posterior crossbites were successfully

Fig 16. Patient 3: pretreatment facial and intraoral photographs.

Table III. Patient 3: cephalometric values

XXX	*Pretretment, 23 y 9 mo*	*Posttreatment, 26 y 3 mo*
SNA	78°	79°
SNB	84°	82°
ANB	−6°	−3°
Facial angle	93°	91.5°
y-axis	60.5°	59.5°
FMA	31°	32°
Mp-SN	38.5°	40.5°
Occlusal plane to SN	13.5°	12°
U1 to SN	113°	111°
IMPA (L1 to MP)	68°	72°
FMIA	84°	76°
Interincisal angle	141°	135°
U1 to A-Pog	5.0 mm	6.0 mm
L1 to A-Pog	4.0 mm	3.0 mm
AO-BO	−13.0 mm	−6.0 mm
E-line: upper	−7.0 mm	−5.0 mm
E-line: lower	−3.0 mm	−2.0 mm
Overjet	0.5 mm	3.0 mm
Overbite	1.0 mm	3.0 mm

corrected by the skeletal expansion of the maxillary suture by the MSE and maxillary protraction by facemask. An ideal overjet was achieved by maxillary protraction and distalization of the mandibular arch. The midline deviation was also corrected by the use of miniscrews in the mandibular arch. The cephalometric analysis revealed that SNA increased from 78° to 79°, SNB decreased from 84° to 82°, and ANB increased from −6° to −3° (Table III). FMA increased from 31° to 32°, indicating a slight clockwise rotation of the mandible (Figs 20 and 21). Relative to the E-line, the upper lip was protracted from −8 mm to −4 mm, and the lower lip was retracted from −3 mm to −2 mm, resulting in an improvement of the concave profile. The PA radiographic analysis showed that the occlusal plane was leveled from −3.0 to −1.0, with a correction of the mandibular asymmetry (Fig 15).

DISCUSSION

Posterior crossbite is a malocclusion that is known to cause several functional and esthetic problems. All 3 patients reported here had a posterior crossbite with asymmetry of the mandible and were candidates for orthognathic surgery. However, all 3 patients refused a surgical plan and strongly preferred treatment with invisible appliances. Thus, we planned to use MSEs for controlling the transverse dimension, miniscrews for

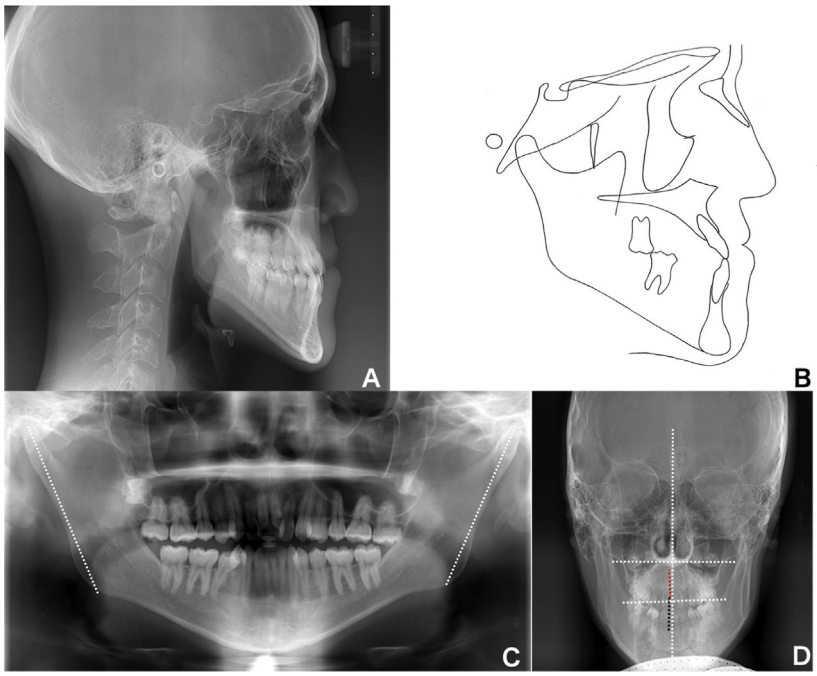


Fig 17. Patient 3: **A-D,** pretreatment cephalometric radiograph, cephalometric tracing, panoramic and PA radiographs. A substantial difference in the length of the condyle is observed (*white* in **C**). The cant of the occlusal plane (*white* in **D**), the dental midline of the maxilla (*red*), and the mandible (*black* in **D**) are indicated in the PA radiograph.

the AP and vertical dimensions, and lingual appliances for the esthetic requirements.

The successful skeletal expansion has been reported with the use of MSEs in the past.[11-13] One of the advantages of using MSE over conventional rapid palatal expansion is the expansion pattern.[16-18] All 3 patients achieved a sufficient magnitude of expansion with a parallel expansion pattern. The expansion jackscrew was secured with 4 miniscrews bicortically between the maxillary first molars, in the sagittal plane, which produces the expansion force directly against the zygomatic buttress bones (positioned lateral to the first molars), the major resisting structure against maxillary expansion,[29] and MSE produced a parallel midpalatal expansion in both palatal and coronal planes.[30,31]

A significant increase in buccal inclination of the molars is often observed after a tooth-borne expansion caused by a fan-shaped movement of the maxilla with dentoalveolar tipping. This dentoalveolar bending could cause the lingual cusps of the molars to extrude and increase the vertical dimension. We aimed to avoid such dentoalveolar movements because all 3 patients exhibited a high angle with an open bite. In our patients, the amount of buccal tipping of the first molars with MSE expansion resulted in average tipping of 3.3°, which is considerably less than that of the tooth-borne expansion.[18] With MSE, a successful expansion with minimal side effects in these patients with high-angle can be achieved.

The first patient required more expansion than the other 2 patients, but because they had not finished growing with patent sutures, we decided to activate the jackscrew only once every 3 days. It took approximately 6 weeks to achieve an ideal buccal overjet. The CBCT images show the parallel opening of the midpalatal suture in the coronal plane (Fig 5, *F*). We also used the MSE after expansion as anchorage for premolar retraction in this patient, which helped to reinforce the anchorage requirements. In addition, one of the suggested effects of maxillary expansion is an improvement of nasal function. The patient mentioned that she could breathe through her nose after the expansion, and she had been a mouth breather before the treatment.

The second patient required asymmetric expansion. Thus, we removed the supporting arms once the buccal cusp of the maxillary left (noncrossbite side) first molar passed the buccal cusp of the mandibular left first molar. For the right (crossbite) side, we expanded the mandibular arch by using cross elastics against MSE and by adding buccal crown torque into the archwire.

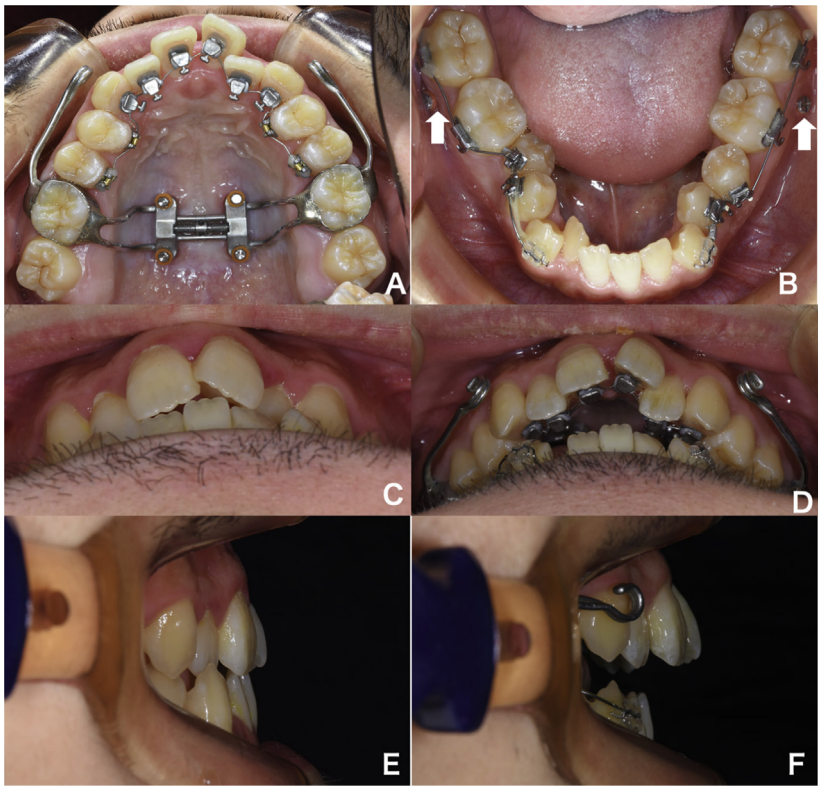


Fig 18. Patient 3: intraoral photographs after expansion. **A,** Maxillary occlusal view after expansion with the protraction hook; **B,** mandibular miniscrews (*white*); **C-F,** occlusal and side views of the anterior relationship before (**C** and **E**) and after (**D** and **F**) protraction of the maxilla.

In the third patient, the orthognathic surgery with midfacial advancement and mandibular setback would generally be the ideal treatment approach. However, because the patient refused the surgical option, we decided to use a facemask to advance the maxilla with a distraction-like disarticulating of the perimaxillary sutures with MSE. The maxilla was protracted with 500 g of force on each side for 8 months while expanding the maxilla. As a result, a slight maxillary advancement was observed even though this patient was mature without any growth potential. We suggest that MSE expansion had an effect not only on the midpalatal suture but also on the pterygopalatine suture and other perimaxillary sutures that contributed to the midfacial changes.[15,17] It is suggested that because MSE expansion loosens the pterygopalatine suture, it reduces the resistance during maxillary protraction resulting in the advancement of the maxilla. One case report of a 24-year-old female patient treated with MSE and facemask indicated that about 3 mm of midfacial protraction was possible.[32] Therefore, combining MSE with a protraction device such as a facemask may have some positive skeletal effect on mature patients with Class III malocclusion. However, further investigation for adults with Class III malocclusion is required to elucidate the changes and long-term stability of the effect using MSE and facemask therapy.

Vertical control is extremely important in patients with a high-angle and/or open bite that require expansion. Miniscrews are known to be efficient devices to control the vertical dimension.[21,22] The use of miniscrews is effective for correcting open bite and canted occlusal plane in patients. Correcting the maxillary occlusal plane often also improves mandibular asymmetry.[22]

In the first patient, miniscrews were used to intrude the molars to correct the open bite. In the maxilla, we first used palatal miniscrews to intrude the molars; however, 1 of the miniscrews failed after using it to retract the premolar. We then placed miniscrews in the buccal bone with some buccal brackets and a lingual button on the molars and premolars to further intrude the maxillary molars. We also placed miniscrews in the mandible to intrude the mandibular molars, but there was no substantial vertical change in the molars; however, we were able to at least prevent extrusion. Extrusion

Fig 19. Patient 3: posttreatment facial and intraoral photographs.

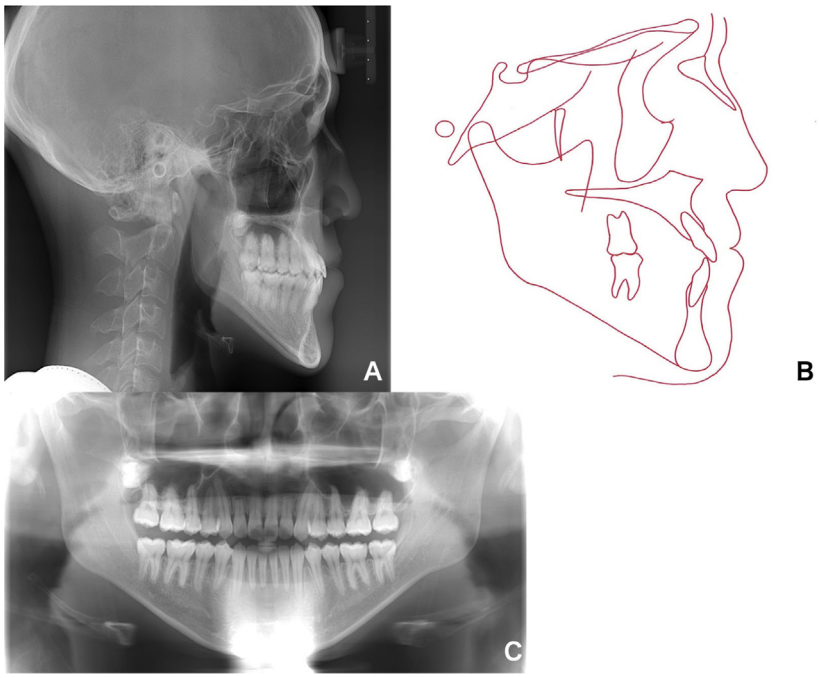


Fig 20. Patient 3: **A-C,** posttreatment cephalometric radiograph, cephalometric tracing, and panoramic radiograph.

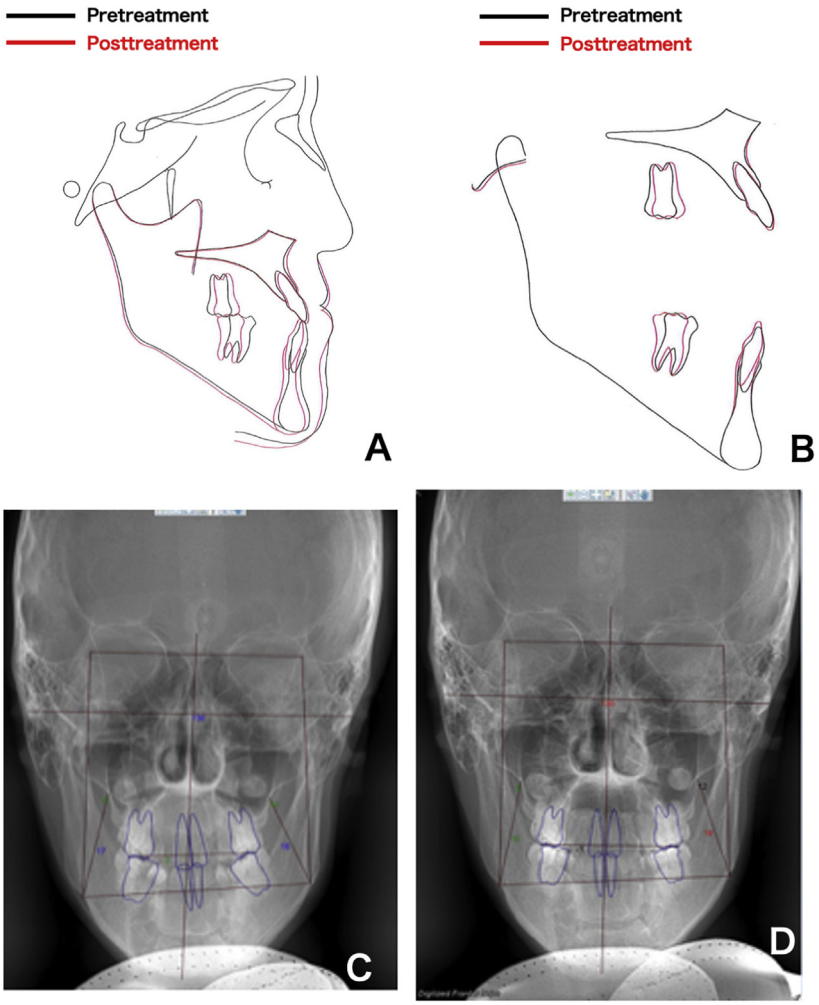


Fig 21. Patient 3: **A** and **B,** pretreatment and posttreatment cranial and regional superimpositions; **C** and **D,** pretreatment and posttreatment PA radiographs. Correction of midline deviation is indicated in the PA radiograph.

of the mandibular molars is often observed after the successful intrusion of maxillary molars in patients with a high angle, decreasing the impact of the open bite correction.[21,33]

In the second and third patients, miniscrews were used to correct the maxillary occlusal cant. In general, the mandible shifts to the side to which the maxillary occlusal plane is tipped upward.[22] In the second patient, the maxillary occlusal plane was canted with the right side down and the left side up, and the mandible was shifted to the left. Miniscrews were used to intrude the maxillary right and mandibular left posterior segments. This correction substantially improved the mandibular shift. In case 3, the occlusal cant was minimal, and we decided to only use miniscrews in the mandible to intrude into the molars. The maxillary occlusal cant was tipped upward on the left side, and thus, the mandibular left posterior segment was intruded.

Ideal AP control is also possible with the use of miniscrews. Miniscrews may be the only device that can provide absolute anchorage, and they enable us to effectively perform asymmetric movement within the arch. In the first patient, because the maxillary second premolars had unusual morphology, we decided to extract them instead of the first premolars. Thus, anchorage control would be critical to effectively retract the anterior segment with en masse movement in this patient, which was successfully accomplished. In the second patient, we had to shift the maxillary arch to the left and the mandible to the right to correct the midline discrepancy. We also used an extended hook from the mandibular molar on the left side to bodily

distalize the posterior segment from the miniscrew and prevented vertical movement. As a result, we were able to move the teeth with precision and correct the midline discrepancy. In the third patient, 1 of the keys for the successful treatment was to tip the mandibular molars distally and retract the mandibular arch to correct the Class III relationship. In addition, because we did not extract any teeth in the mandible, which had 7-8 mm of crowding, distalization of the molars was critical. The superimposition tracing shows that we successfully distalized the mandibular molars by approximately 4 mm. To the best of our knowledge, there is no long-term study that analyzed the stability after mandibular molar distal tipping in patients with Class III malocclusion. One study[34] that compared the treatment outcome between using miniscrews and elastics for patients with Class III malocclusion reported that more distal tipping was observed with miniscrews (average tipping of 3.2°) than with Class III elastics (average tipping 0.9°). However, no data were present during the retention phase. In our patient, distal tipping was at least from 3° to 4°, which may indicate some relapse in long-term observations.

All 3 patients firmly insisted on having lingual appliances. It is known that there are some limitations for lingual appliances compared with labial appliances. The use of lingual appliances may result in a bite-opening effect, increased lingual crown torque,[35] and reduced torque control.[36] The short interbracket distance may also make detailing difficult, and the delivery of uncontrolled forces and moments may put the teeth at risk of root resorption.[37] To overcome the possible disadvantages of lingual appliances, we created a customized bracket torque and angulation prescription for our lingual appliances (Supplementary Fig). The bracket prescription will differ between all patients according to the Angle classification, treatment modality (extraction vs nonextraction), and the relationship between the alveolar bone and the tooth position assessed by CBCT images. For instance, additional torque will be built into the maxillary incisors for patients with Class II Division 2 malocclusion, and more torque will be required for extraction than nonextraction. In addition, if maxillary incisors are uprighted and have less cortical bone on the labial side, we may add some lingual root torque to the bracket. Our clinical considerations for incisor alignment are as follows: (1) avoid excessive torque on the incisors, (2) use low torque for the maxillary central incisors, (3) place the maxillary incisors within one-third of alveolar bone, and (4) place the mandibular incisors in the center of the alveolar bone. Thus, CBCT images provide valuable information in determining the limitations of incisal movement and establishing the ideal bracket torque and angulation in a lingual system.

One of the challenges of maxillary expansion is stability. One study[38] that analyzed the stability after MSE in the short term indicated that there was 39.1% skeletal (nasal floor), 7.1% alveolar, and 53.8% dental expansion, whereas after a year, it resulted in 43.2% skeletal, 15.0% alveolar, and 41.8% dental expansion. This suggests that dental parameters exhibited a greater tendency for relapse than did the alveolar and skeletal measurements. Thus, if you have more dental tipping, it will result in less stable expansion. Using transpalatal arch and heavy rectangular stainless archwire may prevent relapse after expansion. A recent study[39] that compared the expansion effects between MARPE (MSE) and SARME reported that MSE presented a more parallel expansion in both a coronal and axial view. In contrast, SARME led to a V-shaped opening, and the greater buccal inclination of the alveolar process and supporting teeth was observed in the SARME group. Thus, if the relapse is mainly observed from dental tipping, SARME may be more prone to relapse than MARPE. Interestingly, the average dental tipping of MARPE reported was exactly the same amount of tipping (3.3°) that we reported in 1 of our patients, which was half of the buccal tipping they presented by the SARME group. However, long-term follow-up is necessary during the retention in patients with maxillary expansion.

The unstable long-term studies related to rapid palatal expansion are abundant, and they attribute the rapid palatal expansion relapse, largely, to the dentoalveolar area. A long-term study in SARME illustrated that only 41% (skeletal component) was stable after 49 months, indicating that dentoalveolar bending was not stable.[40,41] Recent study[16] illustrated the skeletal component of MSE was 96% with the novel angular measurement and 60% with linear distance measurement, both of which were much higher than the 41% with SARME. Applying the concept of only the skeletal component being stable, MSE should be more stable than SARME.

All 3 patients are considered borderline as to whether treated by camouflage or orthognathic surgery. We were able to treat without surgery with favorable outcomes; however, we would like to emphasize similar patients may not always result in the same quality as our patients. We believe that by using miniscrews and MSE, the range of tooth movement seems to increase without substantial side effects. If the patients were not cooperative or less effect on maxillary expansion, there might have been a different outcome. Therefore, careful examination such as the amount of crossbite, the severity of

asymmetry, occlusal cant, AP discrepancy, bone quality, and quantity by CBCT is required for the decision to treat with camouflage orthodontic treatment.

CONCLUSIONS

The use of MSE enabled us to achieve optimal expansion of the maxilla with minimal dentoalveolar tipping and prevent unwanted clockwise rotation of the mandible during the correction of posterior crossbite. Miniscrews effectively provided anchorage control during the asymmetric space closure, movement of the dental arch, and the anterior retraction without extruding the molars. With a precisely customized setup for each patient, a lingual appliance could achieve an ideal outcome in patients who have esthetic concerns with labial appliances. By combining MSE, miniscrews, and lingual appliances, the patients considered difficult to treat with traditional labial appliances (ie, asymmetric high angle with posterior crossbite) can be successfully treated.

AUTHOR CREDIT STATEMENT

Ryuzo Fukawa contributed to conceptualization, resources, visualization, and original draft preparation; Won Moon contributed to manuscript review and editing; Toru Deguchi contributed to supervision, visualization, and manuscript review and editing; Minoru Aga contributed to resources and manuscript review and editing.

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SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajodo.2021.09.007.

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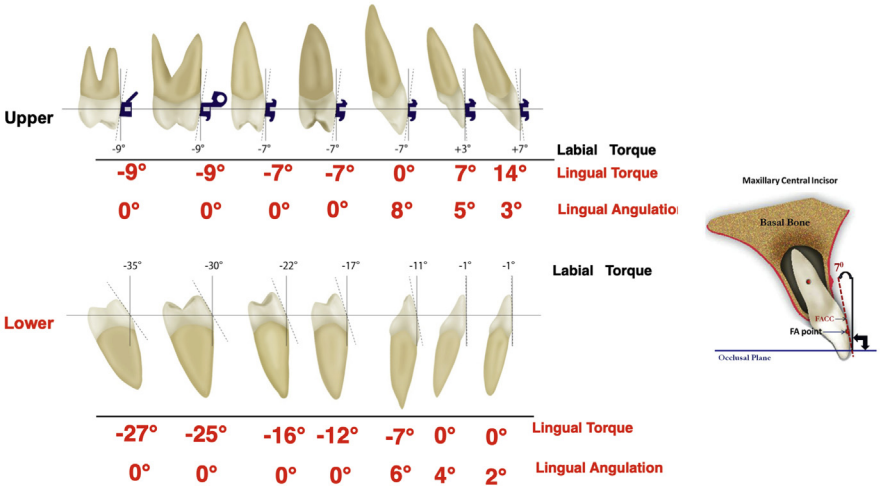

Supplementary Fig. Average prescription of torque and angulation values for lingual brackets compared with labial brackets.