Objectives: The purpose of this study was to evaluate the effects of short-term expansion treatment using the quad-helix appliance on dentofacial morphology in orthodontic patients presenting with a hyperdivergent facial pattern.

Methods: The treatment group consisted of 40 patients with a hyperdivergent facial pattern, who were treated for maxillary incisor crowding with a quad-helix appliance during the mixed dentition period. Lateral cephalograms taken at the start (T0) and end (T1) of the treatment were obtained as a course of care. A similar number of patients, who possessed the same type of facial pattern and who remained untreated, were assigned to a control group. Two consecutive lateral cephalograms of each untreated patient were taken at the same time points as T0 and T1. All cephalograms were traced, analysed and compared between the two groups.

Results: The treatment changes as a result of the quad-helix appliance were expressed in an upward rotation of the mandible (2.34°) and distal tipping and impeded mesial movement of the maxillary first molars. Significant differences were evident between the treatment and control groups.

Conclusion: Quad-helix appliance treatment can be appropriate for significantly decreasing the mandibular plane angle in hyperdivergent patients presenting with moderate maxillary incisor crowding and a positive overjet and overbite.

Introduction

A quad-helix appliance may be used for correcting posterior crossbites and reducing a tooth size-arch length discrepancy during the mixed dentition. It has been reported that quad-helix treatment causes the maxillary first molars to tip and move buccally, lingually or distally and rotate mesiobuccally. The distal tipping and mesiobuccal rotation of the molars can alter the occlusal relationships from Class II to a Class I. Furthermore, the distal tipping of the maxillary first molars results in delayed eruption of the second molars, which delays the prospect of phase II orthodontic treatment.

Several studies have shown that quad-helix treatment induces a downward movement of the maxilla, which secondarily produces a downward and backward rotation of the mandible and a subsequent increase in lower facial height. Additional studies have determined that these results can also be achieved by short-term rapid maxillary expansion treatment. Significantly increased vertical dimension is often accompanied by sagittal and transverse discrepancies. Therefore, growing hyperdivergent patients with a maxillary transverse deficiency may be affected adversely in the vertical dimension by quad-helix treatment.

Contrary studies have reported that there are no
significant increases in the mandibular plane angle in dentoskeletal open-bite patients with hyperdivergent facial patterns treated using a quad-helix appliance and an associated crib. Lineberger et al. found that rapid maxillary expansion could be successfully performed in hyperdivergent patients without detrimental effects on the vertical skeletal relationships and concluded that an increased mandibular plane angle is not a contraindication for rapid maxillary expansion therapy.

No study has assessed the treatment effects of a quad-helix appliance without a crib on dentofacial morphology in hyperdivergent patients. Therefore, the purpose of the present study was to evaluate the short-term treatment effects produced by the use of a quad-helix appliance on dentofacial morphology in Japanese orthodontic patients with a hyperdivergent facial pattern.

Materials and methods

This retrospective study was reviewed and approved by the Research Ethics Committee of the Nippon Dental University of Life Dentistry at Niigata, Japan (ECNG-H-161). The treatment group comprised 40 non-randomised Japanese orthodontic patients possessing a hyperdivergent facial pattern (mandibular plane angle >34.4°). This figure (34.4°), which is greater than the Japanese mean (32.0°) by 1 standard deviation (2.4°), was considered as an appropriate threshold of hyperdivergency. All patients in the treatment group had been treated to alleviate maxillary incisor crowding with a quad-helix appliance in the orthodontic clinic of the Nippon Dental University, Niigata Hospital (Niigata, Japan). The assessment materials were lateral cephalograms taken at the start (T0) and end (T1) of the quad-helix treatment. The cephalometric changes in dentofacial morphology that occurred during the T0 – T1 period were compared with those that occurred during a corresponding period in a control group of patients. At the first clinical visit, each patient was registered with a case number. To avoid sampling bias, when a patient was assigned to the treatment group, a patient of similar age having the nearest case number to the treatment patient and with the same type of facial pattern was entered into the control group. The control group consisted of 40 non-randomised patients who received no orthodontic treatment but were placed under observation and reviewed every two or three months. The lateral cephalograms for the control patients were justified for the purpose of observing the development of dentofacial morphology. In the selection of the treated and untreated patients, the following criteria were adopted: (1) moderate maxillary incisor crowding (<3 mm) with a positive overjet and overbite, (2) fully erupted maxillary first molars and incisors, (3) the presence of primary maxillary second molars at T0, (4) unerupted or incompletely erupted maxillary second molars at T1, (5) consecutive good-quality lateral cephalograms at T0 and T1, (6) no tooth agenesis exclusive of the permanent third molars, (7) no extraction of permanent teeth during treatment/observation, (8) no previous orthodontic or prosthodontic treatment, and (9) no oral habits. Patients were assigned to each group without gender bias, which was based on the statement by Broadbent et al. that no significant gender difference in maxillofacial morphology is apparent before the secondary sex characteristics appear.

The fabrication and activation of the quad-helix appliance were described in previous papers. The appliance was made of 0.8 mm stainless steel wire soldered to maxillary first molar bands and accompanying palatal arms extended mesially to the primary canines or even to the permanent incisors. The appliance was activated primarily to correct a distobuccal rotation of the maxillary first molars and to subsequently expand the maxillary posterior teeth. Prior to cementation, the molar bands were maintained parallel to each other and the extension arms were kept clear of the palatal surfaces of the posterior teeth to allow molar rotation, torque, and intermolar expansion. Patients were seen once a month during treatment and further activation was performed on the palatal arms and lateral bridges using a pair of three-jawed pliers intra-orally or sometimes extra-orally. Following the correction of the molar rotation, the palatal arms were held in contact with the lingual surfaces of the posterior teeth to allow molar rotation, torque, and intermolar expansion. After adequately correcting the arch length discrepancy, the quad-helix appliance was used as a retention appliance, and then removed at T1.

Cephalometric measurement

All cephalograms were taken using the same cephalostat and with standardised settings. The cephalograms of each patient were coded by a co-author (YK) and each
was traced and measured. Twenty-four reference points and nine reference lines were selected and fourteen angular and eight linear measurements were taken to determine changes in dentofacial morphology (Tables I and II, Figure 1). The angular measurements were made to the nearest 0.5° with the aid of a computer system containing a WinCeph analysis software program (Rise Corp, Miyagi, Japan) or a protractor.

### Table 1. Definition of reference points and lines used.

| Reference points | Definition |
|------------------|------------|
| N                | Nasion, the intersection of internasal suture with nasofrontal suture in midsagittal plane |
| S                | Sella turcica, the midpoint of sella turcica |
| Ba               | Basion, the lowermost point on the anterior margin of the foramen magnum in the midsagittal plane |
| Ar               | Articulare, the point of intersection of dorsal contours of mandibular process and temporal bone |
| ANS              | Anterior nasal spine, the point at the tip of anterior nasal spine seen from norma lateralis |
| PNS              | Posterior nasal spine, the point at the tip of posterior spine of palatine bone in hard palate |
| A                | Point A, the deepest midline point on premaxilla between anterior nasal spine and prosthion |
| A’               | The point projected vertically from point A to the palatal plane |
| Ptm              | Pterygomaxillary fissure, the most inferior point of pterygomaxillary fissure |
| Ptm’             | The point projected vertically from Ptm to the palatal plane |
| Or               | Orbitale, the lowest point on lower margin of bony orbit |
| Po               | Porion, the midpoint on upper edge of porus acusticus externus |
| Go               | Gonion, the most inferior, posterior, and lateral point on the external angle of the mandible |
| Pog              | Pogonion, the most anterior point in the contour of the chin |
| Cd               | Condylion, the point at the tip of the mandibular condyle |
| Gn               | Gnathion, the most inferior point in the contour of the chin |
| ABR              | The intersection of the occlusal plane with the anterior ridge of mandibular ramus |
| ABR’             | The point projected vertically from ABR to the mandibular plane |
| B                | Point B, the most posterior point in concavity between infradentale and pogonion |
| B’               | The point projected vertically from Point B to the mandibular plane |
| Me               | Menton, the lowest point on the symphysial shadow as seen in norma lateralis |
| Pm               | Protuberance manti, the most superior point in the contour of the chin |
| Xi               | Xi point, the centroid of mandibular ramus |
| U6MC             | The midpoint between the most convex mesial and distal points on the crown of the permanent maxillary first molar |

| Reference lines | Definition |
|-----------------|------------|
| PP              | Palatal plane, the line joining ANS and PNS |
| FH              | Frankfort horizontal plane, the line joining Po and Or |
| MP              | Mandibular plane, the line tangent to the lower border of the mandible through Me |
| RP              | Ramus plane, the line tangent to the posterior border of the mandible through Ar |
| OP              | Occlusal plane, the line joining the midpoints of the overlapping cusps of permanent first molars and the permanent incisor overbite |
| U1              | The long axis of the permanent maxillary central incisor |
| L1              | The long axis of the permanent mandibular central incisor |
| U6              | The long axis of the permanent maxillary first molar, perpendicular to a line connecting the most convex mesial and distal points on the crown of the permanent maxillary first molar through U6MC |
| PtmV            | The line perpendicular to palatal plane (PP) through Ptm |
and the linear measurements were made to the nearest 0.1 mm using the computer software or a pair of digital sliding calipers.

To avoid any measurement bias, one investigator (IS), who was blinded to the groups, measured the coded cephalograms.

### Statistical analysis

Statistical analyses were performed using a commercially available statistical package (SPSS, Ver17). Means and standard deviations were calculated for each measurement within each group. A one-way analysis of variance (ANOVA) and Scheffe test compared the measurement values between the treatment and control groups at T0 and T1. Unpaired t-tests were used to test the significance of the differences in the treatment changes (T1-T0) between the groups.
Using G power software version 3, a power of the study determined statistical significance at an effect size of 0.8, an alpha error probability of 0.05 and a sample size of 40 for each group when the unpaired t-test was the present study. The analysis showed that the power of this study was 0.94.

### Intra-examiner and inter-examiner reliability

Thirty coded cephalograms were randomly selected and re-measured by the same investigator (IS) and another investigator (WY) independently after an interval of three months. Cronbach’s alpha for each measurement was used to assess intra-examiner and inter-examiner reliability. As shown in Table III, Cronbach’s alpha within the examiners ranged from 0.943 to 0.999, and that between the examiners ranged from 0.946 to 0.999, which demonstrated excellent intra-examiner and inter-examiner reliability. No cephalometric studies assessing intra-examiner and inter-examiner reliability for the angular and linear measurements by the use of Cronbach’s alpha were available. Therefore, the criteria of excellent reliability was based on a previous study that showed high reliability with Cronbach’s alpha of 0.98 in evaluating the scores on a visual analogue scale to judge facial aesthetics. The analysis showed that the power of this study was 0.94.

### Results

The treatment group consisted of 40 patients – 18 boys and 22 girls. The mean ages at T0 and T1 were 8 years 6 months (SD, 1 year 6 months) and 10 years 2 months (SD, 1 year 5 months). The control group consisted of 40 patients – 9 boys and 31 girls whose mean ages at T0 and T1 were 8 years 11 months (SD, 1 year 9 months) and 10 years 8 months (SD, 1 year 10 months), respectively. The lengths of treatment/observation time in the treatment and control groups were 1 year 7 months (SD, 11 months) and 1 year 9 months (SD, 1 year 1 month), respectively. Unpaired t-tests showed no significant differences in the mean ages at T0 ($p = 0.29$) or T1 ($p = 0.15$) or in the mean treatment/observation period of time ($p = 0.50$) between the two groups.

Between the treatment and control groups, significant differences were noted only in maxillary length (ANS-PNS) and sagittal jaw relationship angle (ANB) at T0 (Table IV). The control subjects were considered borderline Class II cases with an ANB angle of 4.75°, while the treatment group had a normal ANB angle of 2.71°. Since significant differences were not noted in any of the other 22 measurements, it was considered acceptable to compare the two groups.

The mandibular plane angle (MP-FH) significantly decreased during T1 and T2 in the treatment group (Table IV). Significant differences were noted in the inclination of the permanent maxillary molar (U6-PP) at T1 between the treatment and control groups (Table IV).

As shown in Table IV, there were significant differences in the ANS-PNS dimension and ANB angle between the treatment group at T0 and the control group at T1. Mandibular length (Cd-Gn) between the control

| Measurement          | Intra-examiner reliability | Inter-examiner reliability |
|----------------------|----------------------------|---------------------------|
| Ba-S-N               | 0.996                      | 0.974                     |
| ANS-PNS              | 0.996                      | 0.974                     |
| A’-Ptm’              | 0.996                      | 0.987                     |
| SNA                  | 0.994                      | 0.998                     |
| PP-FH                | 0.991                      | 0.993                     |
| Go-Pog               | 0.995                      | 0.997                     |
| Cd-Go                | 0.999                      | 0.995                     |
| Cd-Gn                | 0.998                      | 0.999                     |
| ABR’-B’              | 0.998                      | 0.997                     |
| SNB                  | 0.996                      | 0.996                     |
| Npog-FH              | 0.992                      | 0.997                     |
| MP-FH                | 0.943                      | 0.986                     |
| RP-FH                | 0.995                      | 0.997                     |
| MP-PR                | 0.999                      | 0.998                     |
| ANB                  | 0.996                      | 0.998                     |
| ANS-X-Pm             | 0.994                      | 0.996                     |
| U1-FH                | 0.996                      | 0.994                     |
| L1-MP                | 0.999                      | 0.998                     |
| U1-L1                | 0.998                      | 0.995                     |
| U6-PP                | 0.970                      | 0.985                     |
| U6MC-PP              | 0.978                      | 0.946                     |
| U6MC-PtmV            | 0.984                      | 0.986                     |
Table IV. Results of cephalometric measurements for the treatment and control groups at the start and end of the quad-helix treatment.

|                        | Treatment group (N = 40) | Control group (N = 40) | One-way ANOVA (P value) | Schiffe test (P value) |
|------------------------|--------------------------|------------------------|-------------------------|------------------------|
|                        | T0          | T1          | T0      | T1      | TG (T0) vs CG (T0) | TG (T1) vs CG (T1) | TG (T0) vs CG (T1) | TG (T1) vs CG (T1) |
| Skeletal measurement   |              |              |         |         |                   |                       |                       |                       |
| Ba-S-N (degree)        | 128.63      | 128.70      | 127.50  | 126.90  | 0.25 NS            | -                      | -                      | -                      |
| ANS-PNS (mm)          | 47.53       | 48.95       | 50.05   | 50.43   | 0.002 *            | 0.03 *                 | 0.40 NS                | 0.98 NS                |
| A-Ptm' (mm)           | 44.75       | 45.58       | 46.19   | 46.96   | 0.09 NS            | -                      | -                      | -                      |
| SNA (degree)          | 79.92       | 80.68       | 80.56   | 80.92   | 0.72 NS            | -                      | -                      | -                      |
| PPFH (degree)         | 0.66        | 0.81        | 1.16    | 1.40    | 0.71 NS            | -                      | -                      | -                      |
| Go-Pog (mm)           | 68.20       | 70.43       | 69.13   | 70.95   | 0.046 *            | 0.86 NS                | 0.23 NS                | 0.41 NS                |
| Cd-Gn (mm)            | 53.26       | 55.47       | 53.25   | 55.28   | 0.10 NS            | -                      | -                      | -                      |
| Cd-Gn (mm)            | 110.65      | 115.08      | 109.15  | 111.53  | 0.01 *             | 0.88 NS                | 0.13 NS                | 0.65 NS                |
| AN'S'B' (mm)          | 52.23       | 54.04       | 52.05   | 53.70   | 0.11 NS            | -                      | -                      | -                      |
| SNC (degree)          | 77.33       | 77.48       | 76.34   | 76.63   | 0.50 NS            | -                      | -                      | -                      |
| Npog-FH (degree)      | 83.85       | 84.47       | 83.02   | 82.87   | 0.08 NS            | -                      | -                      | -                      |
| MPFH (degree)         | 36.40       | 34.39       | 35.55   | 35.88   | 0.02 *             | 0.65 NS                | 0.03 *                 | 0.97 NS                |
| RPFH (degree)         | 84.10       | 84.87       | 84.26   | 85.40   | 0.61 NS            | -                      | -                      | -                      |
| MRPF (degree)         | 130.92      | 130.00      | 129.76  | 128.84  | 0.38 NS            | -                      | -                      | -                      |
| ANB (degree)          | 2.71        | 3.13        | 2.44    | 2.64    | <0.001 *           | 0.01 *                 | 0.91 NS                | >0.99 NS               |
| ANS+Pm (degree)       | 49.33       | 50.35       | 49.80   | 50.83   | 0.47 NS            | -                      | -                      | -                      |
| Dental measurement    |              |              |         |         |                   | -                      | -                      | -                      |
| U1-FH (degree)        | 112.48      | 114.97      | 111.82  | 111.57  | 0.09 NS            | -                      | -                      | -                      |
| L1-MP (degree)        | 90.28       | 88.80       | 92.79   | 90.76   | 0.08 NS            | -                      | -                      | -                      |
| U1-L1 (degree)        | 122.06      | 121.73      | 121.9   | 123.92  | 0.58 NS            | -                      | -                      | -                      |
| U6-MP (degree)        | 71.70       | 70.43       | 72.15   | 73.91   | 0.03 *             | 0.98 NS                | 0.74 NS                | 0.50 NS                |
| U6-MC-F (mm)          | 18.46       | 19.40       | 18.33   | 19.88   | 0.03 *             | >0.99 NS               | 0.50 NS                | 0.10 NS                |
| U6-MC-PtM (mm)        | 13.80       | 13.84       | 14.03   | 15.64   | 0.050 NS           | -                      | -                      | -                      |

TO indicates the start of the quad-helix treatment; T1, the end of the quad-helix treatment; TG (T0), the treatment group at the start of the quad-helix treatment; TG (T1), the treatment group at the end of the quad-helix treatment; CG (T0), the control group at the start of the quad-helix treatment; CG (T1), the control group at the end of the quad-helix treatment; ANOVA, analysis of variance; NS, not significant.

*<0.05.
group at T0 and the treatment group at T1 was also significantly different but was considered to not provide crucial information for the present study.

The MP-FH and U6-PP angles and the U6MC-PtmV dimension showed significantly different changes between the treatment and control groups (Table V). The mandible rotated upward in the treatment group (2.01°) and downward in the control group (0.33°), which indicated that the total possible mean amount of treatment change in an upward rotation of the mandible was 2.34°. The maxillary first molars tipped distally in the treatment group (1.28°) and mesially in the control group (1.76°), which indicated that the mean amount of possible treatment change in distal tipping of the maxillary first molars was 3.04°. The maxillary first molars moved 0.04 mm mesially in the treatment group and 1.61 mm in the control group, thus demonstrating that the quad-helix appliance

| Table V. Results of treatment changes in cephalometric measurements for the treatment and control groups. |
|--------------------------------------------------------------------------------------------------|
| Treatment group (N = 40) | Control group (N = 40) | Unpaired Test |
|--------------------------|------------------------|---------------|
|                          | Mean | SD   | Mean | SD | P value |
| Skeletal measurement     |      |      |      |    |         |
| Bo-S-N (degree)          | 0.08 | 1.83 | -0.60 | 3.10 | 0.24 NS |
| ANS-PNS (mm)             | 1.43 | 3.62 | 0.38  | 3.75 | 0.21 NS |
| A'-Ptm' (mm)             | 0.83 | 3.46 | 0.78  | 2.71 | 0.94 NS |
| SNA (degree)             | 0.76 | 3.29 | 0.37  | 3.15 | 0.59 NS |
| PP-FH (degree)           | 0.15 | 2.10 | 0.25  | 2.03 | 0.83 NS |
| Go-Pog (mm)              | 2.23 | 3.29 | 1.83  | 2.61 | 0.55 NS |
| Cd-Go (mm)               | 2.20 | 5.57 | 2.04  | 3.78 | 0.88 NS |
| Cd-Gn (mm)               | 4.43 | 8.98 | 2.38  | 6.10 | 0.24 NS |
| ABR'-B' (mm)             | 1.81 | 2.96 | 1.65  | 2.79 | 0.80 NS |
| SNB (degree)             | 0.15 | 2.04 | 0.29  | 2.40 | 0.78 NS |
| Npog-FH (degree)         | 0.63 | 2.06 | -0.16 | 3.22 | 0.20 NS |
| MP-FH (degree)           | -2.01| 2.86 | 0.33  | 2.74 | <0.001 *** |
| RP-FH (degree)           | 0.77 | 4.01 | 1.14  | 3.66 | 0.67 NS |
| MP-RP (degree)           | -0.92| 2.95 | -0.92 | 5.91 | 0.99 NS |
| ANB (degree)             | 0.43 | 1.83 | -0.11 | 2.08 | 0.23 NS |
| ANS-Xi-Pm (degree)       | 1.02 | 5.11 | 1.03  | 3.28 | 0.99 NS |
| Dental measurement       |      |      |      |    |         |
| U1-FH (degree)           | 2.49 | 6.54 | -0.26 | 6.56 | 0.07 NS |
| L1-MP (degree)           | -1.48| 5.08 | -2.03 | 6.84 | 0.68 NS |
| U1-L1 (degree)           | -0.33| 7.17 | 2.74  | 9.32 | 0.10 NS |
| U6-PP (degree)           | -1.28| 3.93 | 1.76  | 4.11 | <0.001 *** |
| U6MC-PP (mm)             | 0.94 | 1.97 | 1.55  | 2.15 | 0.190 NS |
| U6MC-PtmV (mm)           | 0.04 | 2.41 | 1.61  | 3.12 | 0.02 NS |

NS indicates not significant.
*<0.05, ***<0.001.
significantly impeded the movement of the maxillary first molars. The amount of movement change of the maxillary first molars was 1.57 mm less in the treatment group than in the control group. The small changes of the mean MP-FH angle (0.33°) in the control group and the mean U6MC-PtmV dimension (0.04 mm) in the treatment group were considered to be real and not within measurement error, because the intra-examiner and inter-examiner reliability was very high as evidenced by Cronbach’s alpha.

Discussion

In the present study, the mandible rotated upward in the treatment group (2.01°) and downward in the control group (0.33°) with a statistically significant difference. This finding was previously reported by Cozza et al.,11-13 Shundo et al.,4 and Mucedero et al.,15 who showed the upward rotation of the mandible following the use of the quad-helix appliance. However, no significant differences between the quad-helix group and untreated controls were found. Cozza et al.,11,12 and Mucedero et al.,15 used the quad-helix appliance with a crib in dentoskeletal open-bite patients and a hyperdivergent facial pattern (mandibular plane angle of 25 degrees or greater). The minor discrepancy between their results and the current findings might have been due to the dissimilarity in quad-helix and crib design compared with that used in the present study. However, a minor discrepancy in the results between the study by Shundo et al.,4 and the present study could be attributed to the difference in sample selection. Subjects with a hyperdivergent facial pattern were selected in the present study, while Shundo et al.,4 used those with varying facial patterns who were not discriminated on the basis of the mandibular plane angle. Moreover, Cozza et al.,13 and Giuntini et al.,14 showed an upward rotation of the mandible in dentoskeletal open-bite patients with hyperdivergent facial patterns treated using a quad-helix appliance with a crib, without comparison with untreated controls. Studies have shown insignificant decreases or no change in the mandibular plane angle in the treatment group using a similar type of quad-helix appliance to that used in the present study, although subjects were not identified on the basis of their mandibular plane angle.1-3

The result of the present study indicated that the quad-helix appliance could perform slow maxillary expansion successfully to assist in the correction of maxillary incisor crowding in hyperdivergent patients without increasing the mandibular plane angle. This suggests that a high mandibular plane angle is not a contraindication for quad-helix treatment in patients with moderate maxillary incisor crowding and a positive overjet and overbite, and without a posterior crossbite. These findings are supported by Lineberger et al.,16 who reported that rapid maxillary expansion, with a Hass-type expander, was carried out successfully in hyperdivergent patients without adverse effects on the vertical skeletal relationships. However, Cozza et al.,9 and Chung and Font10 showed that short-term rapid maxillary expansion treatment induced a downward and backward rotation of the mandible and therefore an increase in lower facial height.

The present result showing impeded mesial movement of the maxillary first molars was contrary to the findings of Cozza et al.,11-13 and Giuntini et al.,14 who reported that quad-helix treatment promoted mesial movement of the maxillary first molars in hyperdivergent open-bite patients. The contradictory findings might be explained by the fact that the quad-helix appliance with a crib used in their studies was different from the appliance used in the present investigation. In previous quad-helix treatment, tongue pressure might be applied to the crib during swallowing and therefore promote mesial movement of the maxillary first molars. An alternative reason might be related to different quad-helix activation protocols applied in the various studies. In the present study, the molar bands were kept parallel with each other and the palatal arms were kept clear of the palatal surfaces of the posterior teeth so that correction of rotation, torque and expansion of the maxillary first molars were achieved before other posterior teeth were expanded. This likely resulted in the impeded mesial movement of the maxillary first molars. In the studies by Cozza et al.,11-13 and Giuntini et al.,14 however, the quad-helix appliance was expanded by the buccolingual width of one molar for rotation or torque of the maxillary first molars without further activation, thus resulting in the promoted mesial movement of the maxillary first molars.

The present result showing the distal tipping (1.28°) of the maxillary first molars in the treatment group was supported by the studies of Shundo et al.,4 and Kobayash et al.5 However, the distal tipping of the maxillary first molars was larger in the current study (1.28°) than in the studies by Shundo et al. (0.78°).
The impediment of mesial movement and distal tipping of the maxillary first molars caused no extrusion of the maxillary posterior teeth, in turn resulting in an upward rotation of the mandible. The discrepancy in the distal tipping of the maxillary first molars between the past and present studies could be attributed to the difference in sample selection. It has been reported that dolichocephalic (hyperdivergent) subjects have significantly weaker occlusal forces than brachycephalic (hypodivergent) subjects. The subjects with the hyperdivergent facial pattern selected in the present study had weak occlusal force capability, compared with previous subjects of varying facial patterns. Therefore, it was considered to be easy to tip the maxillary first molars distally in the current treatment subjects.

The treatment sample comprised 40 Japanese children drawn from a single centre, which suggested that the current findings and conclusion were low in external validity and unable to be generalized. A method to improve external validity is to conduct multi-centre studies. However, time and cost restraints have limited most studies to single-centre investigations assessing sample sizes of 50 or fewer. Although several single-centre studies have provided supporting evidence indicating that the quad-helix appliance could be applied to treat hyperdivergent patients by decreasing the mandibular plane angle, additional multi-centre clinical studies are needed to improve the evidence base.

In conclusion, quad-helix appliance treatment can be appropriate for significantly decreasing the mandibular plane angle in hyperdivergent patients presenting with moderate maxillary incisor crowding and a positive overjet and overbite.

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Corresponding author

Toshiya Endo, DDS, PhD
Department of Orthodontics
The Nippon Dental University School of Life Dentistry at Niigata
1-8 Hamaura-cho

Chuo-ku
Niigata 951-8580
Japan

Email: endoto@nt.ndu.ac.jp

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