ORIGINAL ARTICLE

Treatment effects of a modified quad-helix in patients with dentoskeletal open bites

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Introduction: The aim of this study was to investigate the effectiveness of a quad-helix/crib (Q-H/C) appliance in a group of growing subjects with thumb-sucking habits and both dental and skeletal open bites. **Methods:** The records of 23 subjects treated with Q-H/C appliances were compared with a control group of 23 untreated subjects with similar vertical relationships. Lateral cephalograms were analyzed before treatment (T1; mean age, 8.4 ± 1.4 years) and immediately after treatment (T2; mean age, 9.9 ± 1.5 years). Mean duration of treatment was 1.5 ± 7 months. The T2-T1 changes in the 2 groups were compared with a nonparametric test for independent samples (Mann-Whitney U test). **Results:** The average increase in overbite during Q-H/C therapy (3.6 mm more than the control group) overcorrected the amount of anterior open bite at T2. However, 4 of 23 subjects did not show positive overbites at T2. Both the maxillary and mandibular incisors had significantly greater lingual inclinations (about 4.0°) associated with greater extrusion (1.4 and 1.0 mm, respectively) in the Q-H/C group than in the control group. In addition, the treated group showed a greater downward rotation (1.2°) of the palatal plane than did the control group. This change was associated with a greater increase in upper anterior facial height (0.7 mm) and a clinically significant reduction in the palatal plane-mandibular plane angle (−1.7°) in the Q-H/C group with respect to the controls. The upper and lower lips showed significant tendencies toward retraction relative to the E-plane in the treated group (2.6 and 2.9 mm, respectively) compared with the controls. **Conclusions:** The Q-H/C appliance was effective in correcting the dental open bite in 90% of growing subjects with thumb-sucking habits and dentoskeletal open bites. The Q-H/C protocol produced a clinically significant improvement in the vertical skeletal relationships because of downward rotation of the palatal plane. (Am J Orthod Dentofacial Orthop 2006;129:734-9)

The prevalence of anterior open bite in North American white children 8 to 11 years of age is 3.6%.[1] Anterior open bite is a common dentoalveolar component of the craniofacial pattern in patients with increased vertical dimension (also called facial hyperdivergence or high-angle facial pattern).[2-4] Significant vertical skeletal imbalances are accompanied by discrepancies in the anteroposterior and transverse dimensions.[2]

Several mechanical and functional factors can be associated with the formation or maintenance of anterior open bites during growth in high-angle patients.[5-9] Abnormal tongue posture (frequently associated with enlarged adenoids or tonsils), tongue thrust, and overall sucking habits also can be involved in sagittal and transverse discrepancies concurrent with vertical problems. The correction of maxillary constriction often is a target for treatment in open-bite patients.[9]

Because of the complex nature, etiology, and dentofacial pattern of high-angle malocclusion, treatment strategies in growing patients range from behavior modification to orthodontic and orthopedic therapy.[7-12] A proposed treatment protocol aimed to eliminate the thumb-sucking habit and correct both the anterior open bite and the maxillary transverse deficiency in growing high-angle subjects is the quad-helix appliance with a tongue crib (Q-H/C).[10] The use of a crib has been advocated to discourage sucking habits by acting as a digit-inhibiting appliance.[7,11,12] A study on dental casts by Villa and Cisneros[13] showed significant closure of the dentoalveolar anterior open bite after palatal crib

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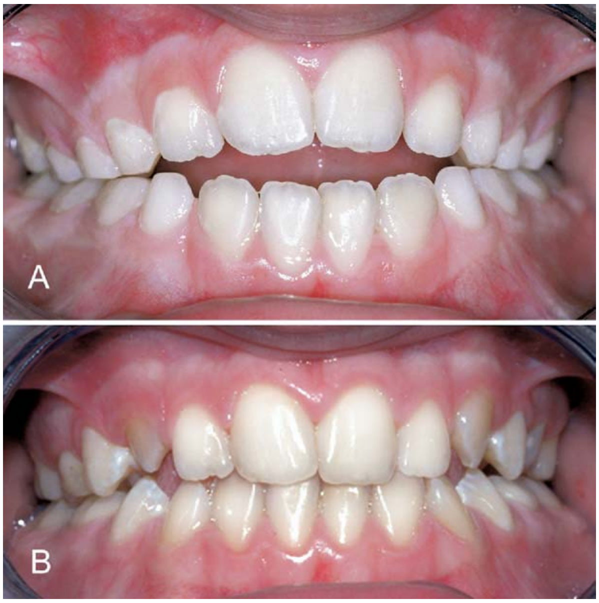

Fig 1. Anterior open-bite correction in mixed-dentition boy: **A,** age 9 years 10 months before treatment; **B,** age 11 years 6 months after treatment.

therapy, with an average increase in overbite of 3.7 mm in treated subjects when compared with controls. Haryett et al[11,14] found that cribs were effective in stopping thumb-sucking habits when they were worn for at least 10 months, whereas Justus[15] reported that tongue cribs could close anterior open bites if worn for 1 year. Huang et al[12] described the effectiveness and acceptable stability of anterior open-bite correction after 14 months of crib therapy in 26 patients with a mean age of 9.5 years at the start of treatment. On the other hand, a previous study by Subtelny and Sakuda[16] questioned the effectiveness of crib therapy in open-bite patients. However, the average age at the start of treatment of the 8 patients in that study was more than 12 years, and the cribs were worn for only 6 months.

To date, the literature lacks comprehensive cephalometric studies on the effects of devices to inhibit thumb sucking in growing patients with anterior open bites. Therefore, the aim of this longitudinal controlled study was to analyze the outcomes of treatment with the Q-H/C appliance in a group of growing subjects with thumb-sucking habits and both dental and skeletal open bites. The changes in the treated group were compared with those in a control group of untreated growing subjects with high-angle malocclusions.

SUBJECTS AND METHODS

The Q-H/C sample was obtained from a group of consecutively treated patients from 1 orthodontic practice. Lateral cephalograms of treated patients were analyzed regardless of treatment results. Each patient had the following features: thumb-sucking habit before treatment; negative overbite; constricted maxillary arch, as part of the thumb-sucking syndrome; full eruption of permanent first molars and permanent incisors (to avoid the "pseudo-open bite" due to under-erupted permanent incisors[5]); no permanent teeth extracted before or during treatment; 2 consecutive lateral cephalograms of good quality with adequate landmark visualization and minimal or no rotation of the head, taken before treatment (T1) and immediately after treatment (T2); treatment with the Q-H/C appliance for at least12 months; and mandibular plane angle relative to the Frankfort horizontal (MPA) of 25° or greater (derived from the cephalometric analysis at T1).[9]

Fig 2. Intraoral view of Q-H/C appliance in place.

The treated sample consisted of 23 subjects, 16 girls and 7 boys. The average age for the Q-H/C group at T1 was 8.4 ± 1.4 years, the mean age at T2 was 9.9 ± 1.5 years, and the mean duration of treatment was 1.5 years ± 7 months. Mean pretreatment value for overbite was −2.5 ± 2.1 mm. The sample included 10 subjects with Class I occlusions, 11 with Class II malocclusions, and 2 with Class III malocclusions.

For the control sample, cephalograms representing T1 and T2 for 23 subjects with hyperdivergent facial patterns (MPA ≥25°) were selected from the archives of the University of Michigan Elementary and Secondary School Growth Study.[17] The sample consisted of 13 girls and 10 boys. The average ages were 9.1 ± 1.6 years at T1 and 11.8 ± 1.3 years at T2. Mean duration of observation was 2.8 ± 1.1 years. The control sample was well matched to the treatment sample, consisting of 11 subjects with Class I occlusions, 11 with Class II malocclusions, and 1 with Class III malocclusion.

The quad-helix used in this study was made of .036-in stainless steel wire soldered to bands on the

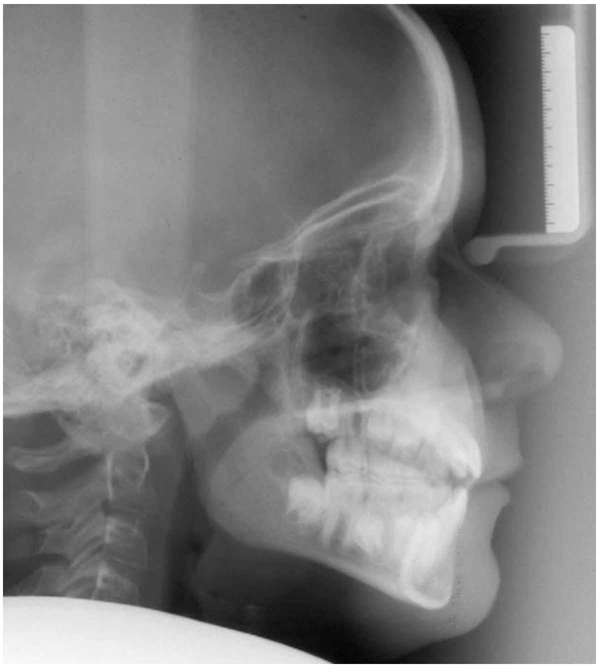

Fig 3. Pretreatment lateral cephalogram (same boy as Fig 1, age 9 years 10 months).

second deciduous molars or the first permanent molars. Its lingual arms were extended mesially to the deciduous canines or even to the permanent incisors. The anterior helices were brought as far forward on the palate as possible (Figs 1-4).

Spurs for thumb-sucking prevention were formed from 3 segments of 036-in stainless steel wire soldered to the anterior bridge of the quad-helix. The tips of the spurs were rounded with a drop of solder. The wire segments were inclined lingually to prevent impingement on the sublingual mucosa.[10] Activation of the quad-helix was equivalent to the buccolingual width of 1 molar.

Cephalometric analysis

The T1 and T2 cephalograms were hand-traced by an investigator (L.F.) and verified for landmark location by another (T.B.). Disagreements were resolved by retracing the landmark or the structure to the satisfaction of both observers. Cephalometric software (Viewbox, version 3.0 [Halazonetis, Kifissia, Greece])[18] was used for a customized digitization regimen that included 78 landmarks and 4 fiducial markers. This program allowed for analysis of cephalometric data and superimposition of serial cephalograms according to our needs.

Lateral cephalograms for each patient at T1 and T2 were digitized, and 50 variables were generated for each film. The magnification factor of the cephalograms was standardized at 8%. A cephalometric and regional superimposition analysis containing measures chosen from the analyses of McNamara,[19] McNamara et al,[20,21] Ricketts,[22] and Steiner,[23] and the Wits appraisal[24] was performed on each cephalogram.

The cranial base superimpositions were accomplished by aligning the basion-nasion line and registering at the most posterosuperior aspect of the pterygomaxillary fissure.[19,22] In addition, the posterior cranial outline was used to verify the superimposition of cranial base structures. From this superimposition, position changes of the maxilla and mandible were measured. To superimpose the maxilla along the palatal plane, the superior and inferior surfaces of the hard palate and internal structures of the maxilla superior to the incisors were used as landmarks. From this superimposition, the movement of the maxillary incisors and molars in the maxilla could be assessed. The mandibular superimposition was performed by using the mandibular canal and tooth germs posteriorly and the internal structures of the symphysis and anterior contour of the chin anteriorly. This superimposition allowed the movement of the mandibular teeth to be measured.

Statistical analysis

Because the length of observation varied between the 2 groups, a direct comparison of the cephalometric changes would be difficult to interpret. To conduct direct and meaningful comparisons, therefore, all cephalometric increments of the untreated controls and the treated patients were adjusted to the average time interval of the Q-H/C sample—18 months. The T2-T1 changes in the 2 groups were compared with a nonparametric test for independent samples (Mann-Whitney U test).

With respect to the clinical significance of the study, the correction of the anterior open bite at the dentoalveolar level was considered clinically effective when the change in overbite measurement produced a positive overlap of the incisors at T2. Because of the sample sizes in the groups, differences between group effects with regard to changes in craniofacial dimensions were considered clinically significant if they were equal to or greater than 1.5 mm or 1.5° (statistical power of the study = 0.83 on the basis of the values for intermaxillary vertical relationships).

The data were analyzed with software (Statistical Package for the Social Sciences, version 12.0, SPSS, Chicago, Ill). Method error was described previously by McNamara et al.[21]

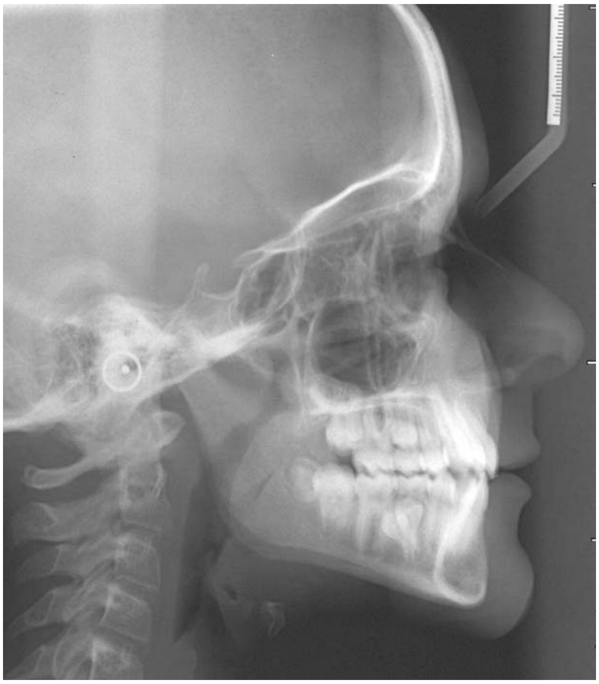

Fig 4. Posttreatment lateral cephalogram (same boy as Fig 1, age 11 years 6 months).

RESULTS

There were no significant differences between the 2 groups for any measurements in the sagittal plane from T1 to T2 (Table). The changes in sagittal growth and position of both the maxilla and the mandible, as well as in the sagittal intermaxillary relationships, were similar in the 2 groups.

The treated group had greater downward rotation (1.2°) of the palatal plane than the control group. This change was associated with a greater increase in upper anterior facial height (N-ANS) (0.7 mm) and a significant reduction in the palatal plane-mandibular plane angle (−1.7°) in the Q-H/C group with respect to the controls.

The treated group showed a significantly greater increase in overbite (3.6 mm more than the control group) that was associated with a significantly greater opening of the interincisal angle (8.7° more than the control group).

Both the maxillary and mandibular incisors exhibited significantly greater lingual inclinations (maxillary central incisor to Frankfort horizontal =−4.1°; mandibular central incisor to MPA = −4.0°) and greater extrusion (1.4 and 1.0 mm, respectively) in the Q-H/C group compared with the control group.

Both upper and lower lips showed significant tendencies toward retraction relative to the E plane in the treated group with respect to the controls (2.6 and 2.9 mm, respectively).

DISCUSSION

This study is the first longitudinal investigation on the effects of crib therapy in growing subjects with dentoskeletal open bites and thumb-sucking habits compared with a control group of untreated subjects with similar vertical relationships. All subjects in both groups had increased vertical facial dimensions. Thumb sucking is regarded as a mechanical factor that can cause anterior open bites in high-angle growing subjects,[5,9] along with constricted maxillary arches.[9]

The placement of the crib led to the discontinuation of thumb-sucking habits in the treated subjects. All stopped the sucking habit immediately. No patient complaints were noted about wearing the appliance.

The initial amount of negative overbite (a measure of anterior dentoalveolar openbite) was −2.5 mm on average in the treated group; this was positive (approximately 1 mm) in the control sample. The average increase in overbite during Q-H/C therapy (3.6 mm) overcorrected the amount of anterior open bite at T2. However, the statistical data should be accompanied by the analysis of individual data: 2 of 23 subjects did not show positive overbites at T2. Therefore, our findings assessed clinical effectiveness for the treatment protocol in approximately 90% of patients with dentoalveolar open bites. A clinically significant amount of lingual inclination of both maxillary and mandibular incisors appears to be a main factor in closing anterior open bite. Furthermore, an average extrusion of about 1.5 mm of the maxillary incisors was associated with an extrusion of 1.0 mm of the mandibular incisors.

The amount of overbite correction in this study (about 3.5 mm) was similar to that in a previous study on dental casts (3.7 mm).[13] In the investigation of Villa and Cisneros,[13] however, 12 experimental and 12 control subjects were studied for an average of less than 4 months, whereas, in our study, the crib was worn for 18 months on average.

The concurrent downward rotation of the palatal plane accounted in part for the lingual inclination of the maxillary incisors in relation to the Frankfort plane. Q-H/C therapy produced a 1.2° difference in the rotation of the palatal plane with respect to the controls. Whereas the untreated subjects showed a tendency to upward rotation of the palatal plane to the Frankfort horizontal plane, the treated group had favorable behavior of the palatal component of intermaxillary vertical relationships. This tendency led to greater (but not clinically significant) increases in upper anterior facial height. As a result, intermaxillary divergence as mea-

Table. Comparison of changes during treatment (T1-T2)

	Q-H/C *n = 23*		*Control* *n = 23*			
Cephalometric measures	*Mean*	*SD*	*Mean*	*SD*	*Difference*	*Significance*
Maxillary skeletal						
SNA angle (°)	−0.6	1.9	−0.2	1.1	−0.4	NS
Pt A to Na perp (mm)	−0.3	2.3	−0.2	0.9	−0.1	NS
Co-Pt A (mm)	2.4	2.2	1.7	0.9	0.7	NS
Mandibular skeletal						
SNB angle (°)	0.2	1.3	0.2	0.7	0.0	NS
Pog to Na perp (mm)	1.1	3.3	0.2	1.0	0.9	NS
Co-Gn (mm)	4.3	1.8	2.9	1.2	1.4	†
Maxillary/mandibular						
ANB angle (°)	−0.7	1.4	−0.4	0.8	−0.3	NS
Wits (mm)	0.0	2.2	−0.1	1.2	0.1	NS
Max/mand difference (mm)	2.0	1.6	1.2	1.0	0.8	NS
Vertical skeletal						
FH to occlusal plane (°)	−0.6	3.1	−1.0	2.0	0.4	NS
FH to palatal plane (°)	0.7	2.1	−0.5	1.0	1.2	*
MPA (°)	−0.8	2.1	−0.3	0.8	−0.5	NS
Palatal plane to mandibular plane (°)	−1.5	1.9	0.2	1.4	−1.7	†
N-ANS (mm)	2.5	1.5	1.8	0.6	0.7	*
ANS to Me (mm)	1.2	2.1	1.2	0.9	0.0	NS
N-Me (mm)	3.8	2.9	3.1	1.1	0.7	NS
Co-Go (mm)	1.7	1.5	1.4	1.4	0.3	NS
Gonial angle (°)	−1.0	2.4	−1.0	1.7	0.0	NS
Interdental						
Overjet (mm)	−0.7	2.5	−0.1	0.6	−0.6	NS
Overbite (mm)	4.4	2.2	0.8	1.5	3.6	‡
Interincisal angle (°)	9.7	9.6	1.0	5.1	8.7	‡
Molar relationship (mm)	0.3	1.0	0.4	0.8	−0.1	NS
Maxillary dentoalveolar						
U1 to Pt A vert (mm)	−0.3	1.7	0.3	0.6	−0.6	*
U1 to FH	−4.9	5.6	−0.8	2.9	−4.1	†
U1 horizontal (mm)	0.2	1.7	0.3	0.8	−0.1	NS
U1 vertical (mm)	2.4	2.0	1.0	1.1	1.4	†
U6 horizontal (mm)	0.9	1.3	0.4	0.6	0.5	NS
U6 vertical (mm)	0.6	0.8	0.3	0.8	0.3	NS
Mandibular dentoalveolar						
L1 to Pt A Pog (mm)	−0.5	1.9	0.3	0.6	−0.8	†
L1 to MPA (°)	−3.9	6.9	0.1	2.7	−4.0	‡
L1 horizontal (mm)	−0.6	2.0	0.3	0.6	−0.9	†
L1 vertical (mm)	2.1	1.2	1.1	0.8	1.0	†
L6 horizontal (mm)	0.4	1.0	1.0	1.1	−0.6	NS
L6 vertical (mm)	1.4	1.5	1.0	1.0	0.4	NS
Soft tissue						
UL to E plane (mm)	1.6	1.6	−1.0	0.8	2.6	‡
LL to E plane (mm)	2.7	6.1	−0.2	1.1	2.9	†
Nasolabial angle (°)	3.7	9.7	2.0	3.6	1.7	NS

Pt A, Point A; *Na,* nasion; *perp,* perpendicular; *Co,* condylion; *Pog,* pogonion; *Gn,* gnathion; *Max,* maxillary; *mand,* mandibular; *FH,* Frankfort horizontal; *MPA,* mandibular plane angle relative to FH; *N-ANS,* upper anterior facial height; *Me,* menton; *vert,* vertical; *Go,* gonion; *U1,* maxillary central incisor; *U6,* maxillary first molar; *L1,* mandibular central incisor; *L6,* mandibular first molar; *UL,* upper lip; *LL,* lower lip.
*$P < .05$; †$P < .01$; ‡$P < .001$; *NS,* not significant.

sured by the angle between the palatal plane and the mandibular plane exhibited a clinically significant improvement of 1.7° in the Q-H/C group with respect to the controls. The Q-H/C protocol produced minimal changes in the inclination of the mandibular plane to the Frankfort horizontal.

The significant modifications in the inclination of both maxillary and mandibular incisors were reflected in the soft-tissue contours. The lingual tipping of the incisors was associated with average 2.6 and 2.9 mm retrusions of the upper and lower lips to the E-plane, respectively.

The results of this study agree with those of previous cephalometric and clinical investigations that demonstrated the effectiveness of crib wear for anterior open-bite closure.[11,12,14,15] The mean duration of crib wear in our sample was 18 months, longer than reported by Haryett et al[11,14] and Justus.[15] However, the clinical recommendation of Huang et al[11,14] to keep the crib in place for more than a year is substantiated by our findings. Lack of success of crib therapy as reported by Subtelny and Sakuda[16] was associated with crib wear of less than 6 months.

The skeletal changes produced by the Q-H/C therapy deserve some attention, because a significant improvement of vertical intermaxillary relationships was part of the therapeutical outcome. The mechanism for this positive result was not represented by a significant change in the position of the mandible in the vertical plane; however, a clinically significant favorable modification in the inclination of the palatal plane in relation to the mandibular plane appeared to be a notable effect of this type of treatment in high-angle growing patients. A long-term study is needed to clarify the stability of these short-term findings.

CONCLUSIONS

The results of this short-term longitudinal study on the use of the Q-H/C appliance in growing subjects with thumb-sucking habits and dentoskeletal open bites showed clinical effectiveness in correcting the dental open bites in 90% of patients and clinically significant improvement in vertical skeletal relationships because of downward rotation of the palatal plane.

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