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Factors contributing to stability of protraction facemask treatment of Class III malocclusion

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Aim: To identify the craniofacial characteristics that contribute to long-term stability of protraction facemask treatment of Class III malocclusion.
Methods: Fifty subjects who met the following criteria were recruited: subjects with an anterior crossbite and 'Wits' appraisal < -3.5 mm; subjects who had been successfully treated with a protraction facemask (at the end of active orthopaedic treatment the overjet was overcorrected by more than 4 mm); the facemask treatment was started at either CS1 or CS2 and the subjects were followed until CS4; no subject had a congenital craniofacial deformity. Based on the occlusal status at CS4, three groups were identified: Stable group (SG), Unstable group (USG) and a Failed group (FG). One-way analysis of variance and Scheffe's post-hoc multiple comparisons were used to analyse the differences between the groups. Stepwise discriminant analysis was used to identify the craniofacial characteristics able to predict the stability of protraction facemask treatment.
Results: There were no statistically significant differences between USG and FG. The N-S-Ar was significantly larger and Co-Gn, Wits and LAFH significantly smaller in the SG group as compared with the USG and FG groups. The critical score between SG and USG was 0.368 and between USG and FG it was -0.981. Individuals with scores higher than 0.368 showed relatively stable occlusions at CS4, whereas anterior crossbites returned in individuals with scores less than -0.981 at CS4. The overall percentage of correctly classified cases was 74 per cent, with 90.0 per cent in SG and 73.3 per cent in FG.
Conclusions: A severe maxillo-mandibular discrepancy, an increased vertical dimension and a prognathic mandible were unfavourable factors for long-term stability following early treatment of severe Class III subjects with protraction facemasks.
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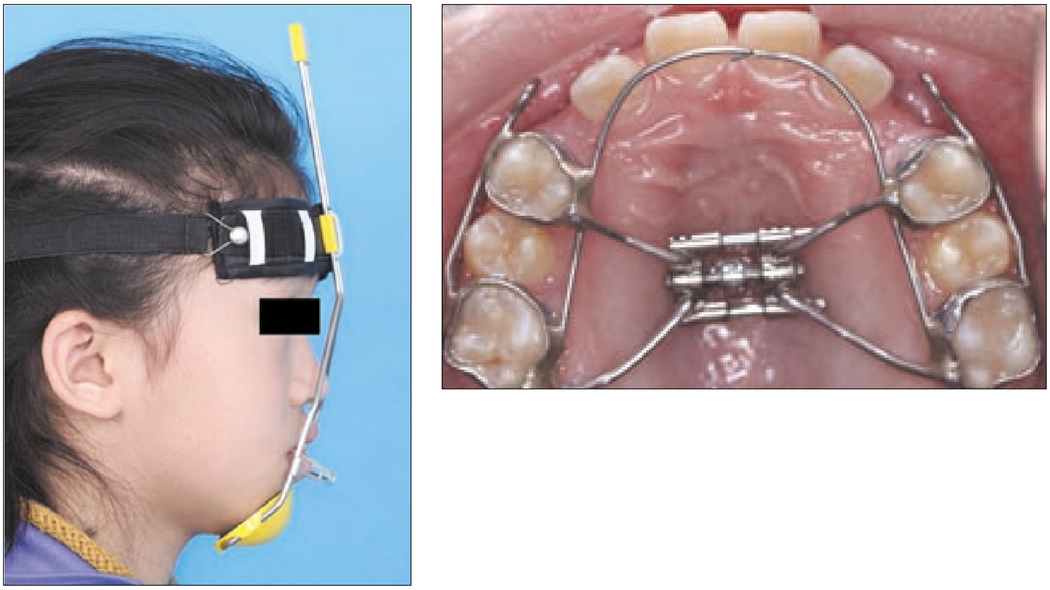
Introduction

The treatment options for Class III malocclusions include orthopaedic treatment, camouflage treatment with comprehensive fixed orthodontic appliances and orthognathic surgery. Early orthopaedic treatment may include chin cup therapy to inhibit forward mandibular growth, facemask therapy to protract the maxillae and treatment with a functional regulator.[1–3] The timing of early orthopaedic treatment depends to some extent on the nature and severity of the skeletal discrepancy and the amount of facial growth remaining. Some clinicians are convinced that early orthopaedic treatment is often a waste of time and resources because the correction relapses, while others believe that treatment in the mixed dentition will eventually normalise a skeletal Class III disharmony.[4–9]

It is generally agreed that the treatment option chosen should address the patient's particular skeletal and/or dentoalveolar discrepancy. In population groups with Class III malocclusions predominately due to maxillary skeletal retrusion, early treatment with a protraction facemask may be an effective method of treatment.[10–15] The major concern of protraction facemask treatment for this type of malocclusion is that the treatment may not be stable in the long-term and, eventually, surgical correction will be required. Obviously, it would be helpful to be able to identify patients with Class III malocclusions that are likely to be stable in the long-term following early orthopaedic treatment with a facemask.

The aim of the current study was to identify the craniofacial features that contribute to long-term stability of protraction facemask treatment. This



(a) (b)

Figure 1. (a) A 10 year-old girl with a protraction facemask. (b) The upper appliance, showing the protraction hooks.

study was based on 50 subjects who had orthopaedic treatment prior to the adolescent growth spurt.

Materials and methods

Sample

Fifty subjects (28 females, Mean age: 9.3 ± 1.7 years; 22 males, Mean age 9.3 ± 1.4 years) who met the following criteria were recruited:

1. The subjects had an anterior crossbite with a 'Wits' appraisal less than -3.5 mm and no functional shift.

2. The negative overjet was overcorrected with a protraction facemask and more than 4 mm of overjet was present at the end of orthopaedic treatment (Figure 1).

3. Facemask treatment was started at cervical vertebral maturation stage CS1 or CS2 and, on average, lasted 12 months. All subjects were followed until CS4.[16]

4. Subjects with congenital craniofacial deformities were excluded.

At CV4 the subjects were classified into the following groups:

1. Stable group (SG): 20 subjects (11 females, Mean age: 9.2 ± 2.1 years; 9 males, Mean age: 9.5 ± 1.3 years) who had ≥ 2 mm of overjet and overbite.

2. Unstable group (USG): 15 subjects (8 females, Mean age: 9.4 ± 1.1 years; 7 males, Mean age: 9.4 ± 1.9 years) with an overjet and overbite between 0 and 2 mm.

3. Failed Group (FG): 15 subjects (9 females, Mean age: 9.4 ± 1.9 years; 6 males, Mean age: 9.0 ± 1.6 years) with an anterior crossbite i.e. overjet ≤ 0 mm.

Cephalometric analysis

The cephalometric variables were measured on lateral cephalometric radiographs taken at the start of treatment (i.e. CV1 or CV2) by one investigator and then verified by another investigator (Table I). Skeletal maturation was assessed by examiners experienced in the CVM method of Baccetti and coworkers.[16] Any disagreements between the two investigators were resolved to the satisfaction of both investigators.

Statistical analysis

All statistical analysis was performed with SPSS 14.0 (SPSS Inc., Chicago, IL, USA). Because of the small number of subjects available, the data from the female and male subjects were pooled. One-way analysis of variance and Scheffe's post-hoc multiple comparisons were performed to compare the groups. Stepwise discriminant analysis was performed to identify the cephalometric variables able to predict the stability of protraction facemask treatment of Class III malocclusion.

Table I. Comparison of the cephalometric variables.

Measurements	SG (N = 20)	USG (N = 15)	FG (N = 15)	p*	p SG vs USG	p SG vs FG	p USG vs FG
Craniofacial							
N-S-Ar	124.7 ± 5.1	119.0 ± 4.1	120.3 ± 3.9	**0.001**	**0.002**	**0.014**	0.809
Maxilla							
A-NFH	-4.5 ± 2.3	-3.3 ± 1.8	-5.2 ± 2.4	0.057	0.261	0.648	0.062
Co-A	80.2 ± 4.6	80.6 ± 4.6	81.7 ± 3.6	0.619	0.973	0.631	0.794
Mandibular							
Pg-NFH	-5.8 ± 6.7	-2.6 ± 4.4	-7.1 ± 6.2	0.111	0.290	0.829	0.130
Ar-Go	46.9 ± 5.6	50.4 ± 5.5	48.5 ± 4.1	0.161	0.421	0.933	0.674
Go-Me	63.8 ± 4.4	66.6 ± 4.9	67.4 ± 6.6	0.125	0.325	0.163	0.925
Co-Gn	108.3 ± 6.5	114.0 ± 6.4	114.3 ± 5.7	**0.010**	**0.040**	**0.028**	0.991
Go angle	125.1 ± 5.4	128.9 ± 5.2	130.5 ± 5.6	**0.015**	0.129	**0.021**	0.743
Maxilla-mandibular relationship							
Wits	-7.8 ± 2.5	-11.6 ± 3.2	-11.9 ± 4.1	**0.001**	**0.007**	**0.003**	0.959
Vertical							
LAFH	60.0 ± 3.4	63.8 ± 4.1	66.5 ± 2.6	**0.000**	**0.009**	**0.000**	0.106
S-Go	75.5 ± 5.9	76.8 ± 6.3	75.5 ± 3.9	0.794	0.796	1.000	0.806
FH-MP	26.9 ± 5.8	29.3 ± 4.9	31.4 ± 5.8	0.066	0.443	0.069	0.596
Dental							
U1-SN	104.2 ± 9.2	106.8 ± 12.7	105.3 ± 6.4	0.749	0.749	0.949	0.919
L1-FH	63.2 ± 8.4	64.8 ± 8.4	63.9 ± 7.0	0.434	0.466	0.982	0.617
Soft tissue							
UL E Line	-1.6 ± 2.4	-1.1 ± 2.0	-0.4 ± 2.0	0.262	0.791	0.262	0.663
LL E Line	1.9 ± 2.9	3.0 ± 2.6	3.5 ± 3.3	0.238	0.505	0.271	0.911
Nasolabial angle	103.0 ± 12.9	102.4 ± 10.9	110.6 ± 10.3	0.104	0.990	0.174	0.171

* ANOVA
Significant values in bold ($p < 0.05$)

Method error

Thirty randomly chosen lateral cephalometric radiographs were digitised and remeasured two weeks apart and Dahlberg's method errors calculated.[17] The combined error did not exceed 0.3 mm for the linear variables and 0.5 degree for the angular variables.

Results

The cranial base angle (N-S-Ar) was significantly larger in the SG group (Mean: 124.7 degrees) as compared with the USG (Mean: 119.0 degrees) and FG (Mean: 120.3 degrees) groups. There were no statistically significant differences between the FG and USG groups (Table I).

There were no significant differences in maxillary position, as evaluated by the perpendicular distance from A point to the perpendicular to Frankfort horizontal through N (A-NFH) and the mandibular condyle to A point distance (Co-A). In the mandible, the gonial angle (Go angle) was significantly larger in FG than that in SG (Table I). Mandibular length (Co-Gn) was significantly larger in the USG and FG as compared with SG. The mean values for SG, USG and FG were 108.3 mm, 114.0 mm and 114.3 mm, respectively. However, the mean values of Ar-Go and Go-Me were similar among the three groups (Table I).

The maxillo-mandibular discrepancy in the SG was significantly smaller (-7.8 mm) than the

Table II. Discriminant analysis.

Predictive variables	Standardised canonical discriminant function coefficients	Unstandardised canonical discriminant function coefficients
N-S-Ar	0.633	0.141
Wits	0.494	0.151
LAFH	-0.753	-0.218
Constant		-1.859

Individual score = 0.141 x (N-S-Ar) + 0.151 x (Wits) - 0.218 (LAFH) - 1.859
Group centroids: SG = 1.471; USG = -0.735; FG = -1.227

Table III. Group classification based on the discriminant analysis.

Group	Predicted group membership			
	SG	USG	FG	Total
Original count				
1	18	2	0	20
2	2	8	5	15
3	0	4	11	15
Per cent				
1	90.0	10.0	0.0	100.0
2	13.3	53.3	33.3	100.0
3	0	26.7	73.3	100.0

74 per cent of the original cases were correctly classified

maxillo-mandibular relationships in both the USG (-11.6 mm) and FG (-11.9 mm) groups (Table I).

The mean lower anterior facial height (LAFH) in SG, USG and FG were 60.0 mm, 63.8 mm and 66.5 mm, respectively. Significant differences were noted when SG was compared with USG and the FG (Table I). There were no significant differences in the Frankfort mandibular plane angle (FH-MP) between the groups.

There were no statistically significant group differences in the inclinations of the incisors (U1-SN, L1-FH) or the soft tissue measurements (UL E line, LL E Line, Nasolabial angle).

Discriminant analysis

Stepwise analysis was performed to generate three variables: Cranial base angle (N-S-Ar), Wits and lower anterior facial height (LAFH). Unstandardised canonical discriminant function coefficients of the selected variables, along with a constant, led to the following equation: Individual Score = 0.141 x (N-S-Ar) + 0.151 x (Wits) - 0.218 (LAFH) - 1.859 (Table II). The critical score between the SG and USG was 0.368 and the critical score between USG and FG was -0.981. The results suggest if a patient's score is higher than 0.368, early treatment with a protraction facemask would result in a relatively stable occlusion at the cervical vertebral maturation stage CV4. On the other hand, if an individual's score is less than -0.981, the incisors are likely to relapse into a crossbite by the end of adolescent growth spurt (CV4).

In the present study, the percentage of correctly classified cases based on the above equation was 74 per cent, with 90.0 per cent in the Stable Group and 73.3 per cent in the Failed Group (Table III).

Discussion

Previous studies have reported that Class III malocclusions become more pronounced with growth.[18] Therefore, orthopaedic treatment of skeletal Class III malocclusions in either the mixed or the deciduous dentition has received increasing attention. Treatment timing is, however, complicated due to the variability in craniofacial growth and the different responses to this form of treatment. Confidence in early treatment of these difficult malocclusions has been shaken by malocclusions that, although successfully corrected in childhood, relapsed in adolescence. Discriminant analysis had been used in previous studies to predict the outcomes to different forms of Class III treatment.[19–26]

Some previous studies have graded the treatment outcomes into two groups: a successfully treated group and a failed or relapse group. In our experience a two-point method does not include all responses to early orthopaedic treatment. We found a borderline group of cases with close to zero overbite and overjet that were not covered by a simple two-point scheme, so we graded the occlusal outcomes at CV4 into Stable, Unstable and Failed groups. We also decided to use cervical vertebral maturation to describe the developmental status of our subjects because chronological age is associated with wide variation in the timing of spurts in facial growth. Cervical vertebral maturation, on the other hand, is regarded as an acceptable indicator of skeletal maturity and the adolescent growth spurt.[16,27–28]

A protraction facemask has become an accepted method of early orthopaedic treatment of skeletal Class III malocclusions because the majority of these malocclusions have a maxillary skeletal retrusion.[14–15] However, as treatment with a facemask usually ceases in the mixed dentition and further facial growth will occur, these subjects should be followed to determine if additional orthodontic and/or surgical treatment is needed. The stability of protraction facemask treatment depends, to a large extent, on the magnitude and direction of late growth in the face. Previous longitudinal studies have demonstrated that the adolescent peak in mandibular growth in Class III subjects occurs between cervical vertebral maturation stages 3 and 4 (CS3 to CS4). Between the late maturation stages of CS4 and CS6, increases in mandibular length in females and males with Class III malocclusions were two to three times more than in subjects with normal occlusion. Furthermore, increases in the vertical dimension become apparent at late maturation stages.[29] In the present study, an anterior crossbite at follow-up did not automatically mean that surgical intervention was required: some of these patients were treated with additional orthodontic treatment.

We used skeletal, dental and soft tissue measurements that may influence the outcome of treatment. The first variable extracted by the discriminant analysis was the cranial base angle (N-S-Ar). We found that an acute N-S-Ar angle was associated with a prognathic mandible and was a good indicator that protraction facemask treatment was unlikely to be successful in the long-term. Others have reported that the cranial base angle becomes more acute in growing Class III subjects and, as a result, a prognathic profile develops with age.[13,30–33]

It is interesting to note that neither maxillary position nor maxillary size significantly influenced the long-term treatment outcome with a protraction facemask. Some investigators have reported that the mandible in skeletal Class III malocclusions is larger, but similar in shape, to an average-size mandible.[34–35] Other investigators have reported that although mandibular length was increased in Class III malocclusions, an obtuse gonial angle was the major contributor to the prognathism.[9–11,13,36] Our findings are in agreement with this latter view: we found small, but statistically significant, differences in the gonial angle and the length of the mandibular body (Co-Gn) between SG and FG. In the present study, no parameters describing the position and size of the mandible were identified in the discriminant model. Although our findings indicated that mandibular shape (Co-Gn, Go angle) were important factors in occlusal stability, the discriminant analysis disclosed that the maxillo-mandibular relationship, as assessed by the Wits appraisal, was a more important factor for long-term stability of facemask treatment.

In agreement with previous studies, we confirmed that increases in lower anterior face height during and following adolescence are likely to lead to unfavourable occlusal changes following facemask treatment.[9–11,13,29,37] The mean lower anterior facial height in the FG was significantly larger than the lower anterior face height in the SG.

The predictive model developed in the present study primarily identifies the good responders to early treatment with a protraction facemask, but it does not distinguish between surgical and non-surgical patients. In the Failed and Unstable groups alternative orthodontic therapies should be considered. Class III malocclusion is a heterogeneous and complex anomaly with a distinct craniofacial pattern, established early in development. It often becomes more severe with age, leading to a marked skeletal sagittal imbalance. Due to the fact that some Class III malocclusions deteriorate over time, there is a need to identify patients who would benefit from early treatment of the discrepancy. Although this study indentified some cephalometric measurements that can be used to predict the outcome of facemask treatment, the model would be improved with a larger sample. This suggests that a multicentre study and the addition of transverse parameters, which are often features of maxillary hypoplasia, may improve the predictive power of the discriminant model.

Conclusions

A severe maxillo-mandibular discrepancy, an increased vertical dimension and a prognathic mandible were unfavourable factors for long-term stability following early treatment of severe Class III subjects with protraction facemasks.

The ability to predict the outcome of facemask treatment at the mixed dentition stage is an important advance for orthodontists.

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