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Floating norms and post-treatment overbite in open bite patients

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SUMMARY In this study, the clinical significance of three floating norm systems, the Bergen Box (BB), the Segner–Hasund Harmonybox 1 and 2 (SHH1 and SHH2), as well as the influence of treatment modalities for predicting results of an open bite treatment were investigated. In the BB and SHH1, patients with a steep mandibular plane angle or a skeletal open bite configuration (O1mand, O1mandmax, O1max, or N1mand) were considered 'high risk', while in the SHH2, only the configurations O1mand and O1mandmax were considered high risk. All other configurations were designated 'low risk'. It was postulated that in high risk patients, the overbite was likely to relapse into an open bite after retention.

Cephalograms of 83 open bite patients taken before treatment (T1) and at the end of retention (T2) were studied. Patients designated as low risk generally had a normal overbite at T2 after treatment, regardless of which box was used. The risk configurations of the SHH1 and SHH2 at T1 were significant predictors of the overbite at T2, the first being slightly better compared with the SHH2. The main clinical values of the SHH1 and SHH2 are strongly supported by the relatively good success rate in distinguishing a low-risk configuration. Reliable prediction of the treatment results of high-risk patients with risk configurations according to the SHH is improved by evaluating treatment modalities. The posterior bite splint seemed to have a bite opening effect, while a bite closing effect was associated with the use of a removable retention appliance.

Introduction

The treatment of an open bite in the incisor region is one of the most challenging aspects of orthodontics. Two types of open bite can be distinguished. The dento-alveolar open bite has morphological aberrations confined to the dento-alveolar region and is often associated with abnormal functional conditions, such as a thumb-sucking habit (Nahoum *et al.*, 1972; Cangialosi, 1984; Harzer *et al.*, 1989). If the habit is terminated or if an appliance is worn, the open bite often closes (Subtelny and Sakuda, 1964; Van der Linden and Boersma, 1984; Proffit and Fields, 1993). A dental open bite can also coincide with a skeletal open bite configuration, i.e. an enlarged lower face height and an increased mandibular plane angle (Enunlu, 1974; Mizrahi, 1978; Frost *et al.*, 1980; Cangialosi, 1984; Ellis and McNamara, 1984; Fields *et al.*, 1984; Lopez-Gavito *et al.*, 1985).

Orthodontic treatment of a skeletal open bite is difficult and relapse is frequently observed (Subtelny and Sakuda, 1964; Safirstein and Burton, 1983; Van der Linden and Boersma, 1984; Segner and Hasund, 1998). In order to avoid prolonged treatment, the vertical skeletal dimensions should be evaluated early in order to decide which treatment approach is appropriate. It would be advantageous to select patients who cannot be successfully treated by conventional orthodontics and avoid unnecessary treatment during puberty. However, there appears to be no universally accepted norm for a skeletal open bite, which is diagnosed by visual inspection of the patient in norma lateralis (Schendel *et al.*,

	SNA	NL-NSL	NSBa	ML-NSL	SNB	ML-NL
	72.0	18.5	150.0	52.0	70.0	33.5
	73.0	17.5	148.0	50.0	71.0	32.5
	74.0	16.5	146.0	48.0	72.0	31.5
open	75.0	15.5	144.0	46.0	73.0	30.5
	76.0	14.5	142.0	44.0	74.0	29.5
	77.0	13.5	140.0	42.0	75.0	28.5
	78.0	12.5	138.0	40.0	76.0	27.5
	79.0	11.5	136.0	38.0	77.0	26.5
	80.0	10.5	134.0	36.0	78.0	25.5
	81.0	9.5	132.0	34.0	79.0	24.5
normal	82.0	8.5	130.0	32.0	80.0	23.5
	83.0	7.5	128.0	30.0	81.0	22.5
	84.0	6.5	126.0	28.0	82.0	21.5
	85.0	5.5	124.0	26.0	83.0	20.5
	86.0	4.5	122.0	24.0	84.0	19.5
	87.0	3.5	120.0	22.0	85.0	18.5
	88.0	2.5	118.0	20.0	86.0	17.5
deep	89.0	1.5	116.0	18.0	87.0	16.5
	90.0	0.5	114.0	16.0	88.0	15.5
	91.0	0.0	112.0	14.0	89.0	14.0

Figure 1 The Bergen Box (BB). Norm values according to the BB. For an individual patient, the skeletal configuration is harmonious if all variables are located on a horizontal line. Deviations indicate which jaw is aberrant. The angle ML–NL determines whether a patient is convergent or divergent. The threshold values for the angle ML–NL are indicated with dotted lines. For details concerning the BB refer to Hasund *et al.* (1974). Published with kind permission of Professor A. Hasund.

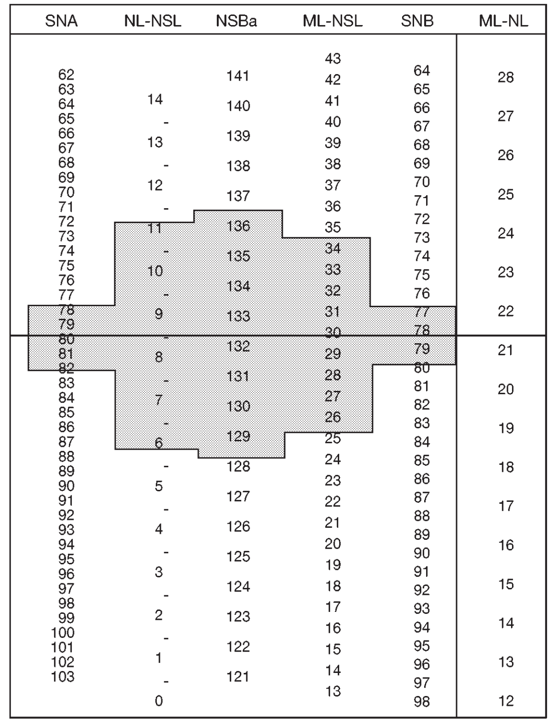

Figure 2 The Segner–Hasund Harmonybox (SHH). Norm values according to the SHH. For an individual patient, the skeletal configuration is harmonious if all variables are located on a horizontal line. Deviations indicate which jaw is aberrant. The grey-coloured surface indicates the range of the standard error for each measurement (which is predicted by the other measurements) for this individual harmonyline. For details concerning the SHH refer to Segner (1989), and Segner and Hasund (1998). This classification will be denoted as SHH1. Another classification method based on this table was also used (SHH2). For further details see Table 1.

1976; Fields *et al.*, 1984) or with the use of fixed threshold values for lower face height and mandibular inclination (Tweed, 1954). Hasund *et al.* (1974) used the accepted norms of Björk (1947), and developed floating norms for some commonly used sagittal and vertical measurements. These norms are represented in the Bergen Box (BB). Segner (1989) investigated a mixed sample of subjects of Norwegian and middle-European origin and developed alternative floating norms, which are represented in the Segner–Hasund Harmonybox (SHH) (Segner, 1989; Segner and Hasund, 1998). The standards for the BB (Figure 1) and the SHH (Figure 2) are related to the individual skeletal configuration, rather than the population mean. Consequently, individual norms according to the BB and the SHH for patients with different skeletal configurations may vary.

In this study, the clinical significance of the BB and of two variants of the SHH, denoted as SHH1 and SHH2 (for explanation see Table 1), were tested to investigate whether subgroups with a large risk of maintaining an open bite during treatment could be distinguished.

Materials and methods

From the archives of the Department of Orthodontics at the University of Hamburg, 380 subjects with a pre-treatment dental anterior open bite (AOB) were selected from a cohort of 6500 patients. The selection was performed by inspection of the pre-treatment cephalograms. The AOB was defined as a missing overlap of the maxillary and the mandibular incisal edges relative to the occlusal plane. From this group of 380 subjects, patients were only included if:

1. they had completed orthodontic treatment at the unit;

Table 1 Classification methods and configurations of the BB, SHH1, and SHH2.

1. BB

	ML–NL > 26.5	26.5 ≥ ML–NL ≥ 20.5	ML–NL < 20.5	
Index < 76	O1	O2	O3	Open
Index ≥ 76 ≤ 82	N1	N2	N3	Neutral
Index > 82	T1	T2	T3	Deep
	Hyperdivergent	Normal	Hypodivergent	

NL deviates from the harmonyline: subclassification: max.
ML deviates from the harmonyline: subclassification: mand.
NL and ML deviate from the harmonyline in opposite directions: subclassification: mandmax.

2. SHH1

	ML > 6º above NL*	ML ± 6º of NL*	ML > 6º below NL*	
Index < 71	O1	O2	O3	Open
Index ≥ 71 ≤ 89	N1	N2	N3	Neutral
Index > 89	T1	T2	T3	Deep
	Hyperdivergent	Normal	Hypodivergent	

NL deviates from the harmonyline: subclassification: max.
ML deviates from the harmonyline: subclassification: mand.
NL and ML deviate from the harmonyline in opposite directions: subclassification: mandmax.
*This indicates the position of the value for NL in relation to ML within the box.

3. SHH2

	NL below SE or ML above SE*	NL and ML within SE*	NL above SE or ML below SE*	
Index < 76	O1	O2	O3	Open
Index ≥ 76 ≤ 82	N1	N2	N3	Neutral
Index > 82	T1	T2	T3	Deep
	Hyperdivergent	Normal	Hypodivergent	

NL outside the SE and ML within SE: subclassification: max.
NL within SE and ML outside the SE: subclassification: mand.
NL and ML outside the SE in opposite directions: subclassification: mandmax.
For explanation of the measurements mentioned, refer to Figure 3.
*SE indicates the standard error for the prediction of the measurement by the other measurements.

2. documentation was complete, including cephalograms taken before treatment and at the end of retention;
3. they were of Caucasian origin;
4. they did not have severe craniofacial disorders such as cleft palate or hemifacial microsomia.

No selection was made on the basis of skeletal configuration, gender, duration, method, treatment result, or age before treatment.

The records showed that some patients who were treated with removable appliances only, consistently did not wear their appliances, which resulted in interruption of treatment. It was decided to exclude these patients, regardless of the skeletal configuration and dental occlusion at the time of treatment interruption, although this posed a risk of selection bias. Furthermore, patients were omitted when orthognathic surgery was originally planned and performed. Patients initially treated orthodontically where this was unsuccessful were included in the study as the initial orthodontic treatment was directed at increasing the overbite. The records taken at the end of orthodontic treatment, before referral to the orthognathic surgeon, were then considered as the records at the end of retention. The final sample included 83 patients (51 female, 32 male).

The lateral cephalograms from the beginning of treatment (T1) and from the end of the retention period (T2) were traced. For the digitizing process, a Scriptel® (Scriptel Corporation, Columbus, Ohio, USA) digitizer connected to a personal computer was used. Fifteen landmarks and four additional constructed landmarks were recorded. The landmarks were defined according to Segner and Hasund (1998). A custom-made software package, written by one of the authors, was used for storage of the landmark coordinates and for calculating the measurements. Six reference lines and 11 measurements were computed (Figure 3).

From each patient, gender and age at T1 and T2 were recorded, as well as the occurrence of sucking habits, tongue thrusting, mouth breathing, enamel hypoplasia, and any pre-treatment tooth loss (due to agenesis or extraction). The following treatment methods were recorded: removable appliances (maxilla or mandible), lingual arch, posterior bite splint, palatal crib, fixed appliance (maxilla or mandible), trans-palatal arch, headgear, functional appliance, chin cap, removable or fixed retainer, and extractions.

Each patient was classified with the cephalograms at T1 and T2 according to the BB, the SHH1 and SHH2 (Table 1).

Based upon the overbite at the end of retention, the total sample was divided into two groups according to the method used by Ellis and McNamara (1984). An overbite smaller than 0 mm at the end of retention designated a patient into the open bite group, and if the overbite was equal to or larger than 0 mm at the end of retention, the patient was placed in the normal overbite group.

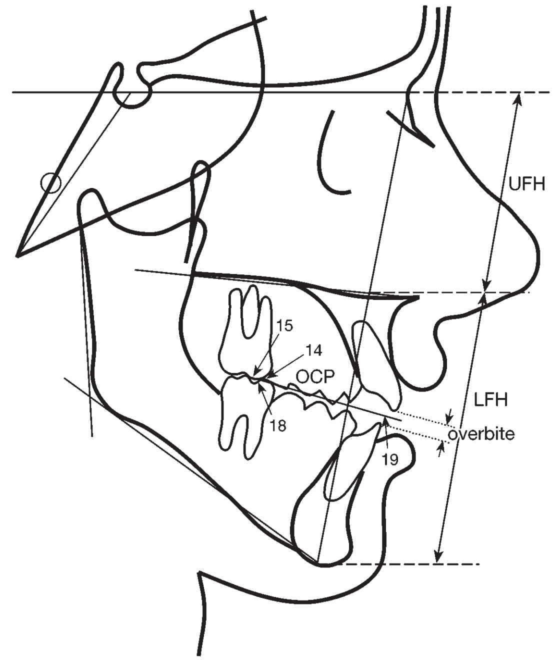

Figure 3 Cephalometric landmarks, reference lines, and measurements. Landmarks, reference lines, and measurements used in this study are described by Segner and Hasund (1998). The index was calculated using the following formula: Index = UFH/LFH. The following measurements were designed especially for this study:

Landmarks

14 Mesial cusp of the mandibular first permanent molar

15 Mesial cusp of the maxillary first permanent molar

18 Occlusal plane anterior

19 Occlusal plane posterior

Reference lines: occlusal plane (OCP) connecting the midpoints between the incisal ridges of the central incisors (point 18) and the midpoint between the mesiobuccal cusps of the first molars (point 19). Measurements: overbite: the distance between the incisal tips of maxillary and mandibular central incisor perpendicular to the occlusal plane. Positive values for the overbite indicate a normal or deep bite, while an open bite is indicated by negative values.

The interaction between gender and treatment result was tested using chi-square statistics, and found to be non significant. In order to maintain reasonable group sizes, no separation of gender was performed for the statistical analyses. Some configuration groups were very small, making statistical analysis impossible, and combining several configurations into larger groups was necessary. For each classification, 'high' and 'low' risk groups were defined on the basis of clinical experience and preliminary investigations as follows:

BB and SHH1: The configurations O1mand, O1mandmax, O1max, and N1mand were combined into the high risk group, the other configurations formed the low risk group.
SHH2: The configurations O1mand and O1mandmax were combined into the high risk group, the other configurations formed the low risk group.

Figure 4 shows the general clinical appearance of each high risk and low risk configuration.

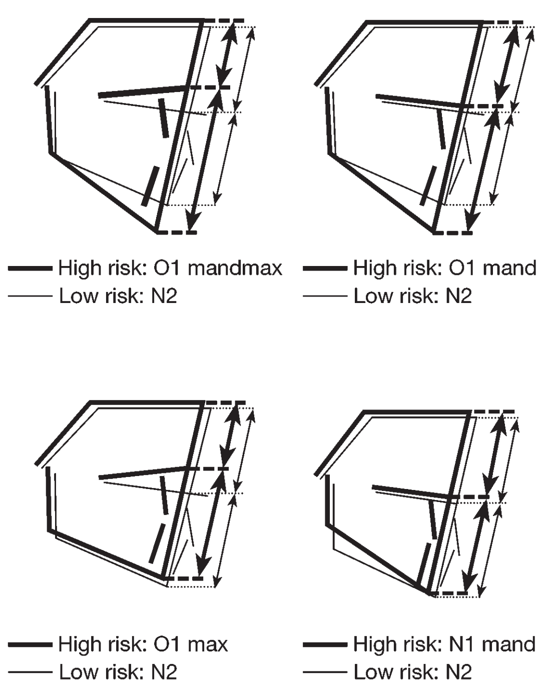

Figure 4 Diagrammatic representation of high and low risk configurations. Thin lines indicate a patient with an N2 configuration low risk and thick lines high risk patients with an O1mandmax, O1mand, O1max, or N1mand configuration. Note the difference in mandibular inclination between the configurations O1max and O1mandmax, whereas both configurations are comparable with regard to the index and palatal inclination.

Differences between high and low risk group configurations were tested by means of Student's *t*-tests. Logistic regression analysis was used in order to evaluate the relative importance of the anamnestic data, type of appliances used, and the risk group configurations of the BB, SHH1, and SHH2 classifications for the overbite groups at the end of retention.

In order to eliminate errors during digitization, each tracing was recorded twice, the second being performed at least two weeks after the first. The values for each pair of recordings were averaged, and the mean values were used for subsequent classification and statistical analysis. Furthermore, reliability of the measurements was analysed by repeated tracing and digitizing of 20 cephalograms. The second tracing was performed at least two weeks after the first. Systematic errors were tested using the paired Student's *t*-tests. The size of the method error (Dahlberg, 1940) and the coefficient of reliability according to Houston (1983) were calculated. For all statistical analyses, a confidence level $P < 0.05$ was considered significant.

Results

Error study

No systematic errors were found. The Dahlberg method error ranged from 0.23 to 1.13. All variables used in the study had coefficients of reliability above 0.99, except for the angles NSBa (0.95) and NL–NSL (0.96).

Distribution of the pre-treatment skeletal configurations (T1)

Figure 5 shows that the SHH1 designated most patients into the configurations N1mand and N2, the open bite configuration groups were smaller (22 patients), while very few subjects were designated into the deep bite configuration. In the BB, the open bite configurations were larger than the neutral and the deep bite configurations, the O1max being the largest group. The deep bite configuration groups of the BB were larger compared with the SHH1. The hypodivergent subgroups consisted of only a very few patients.

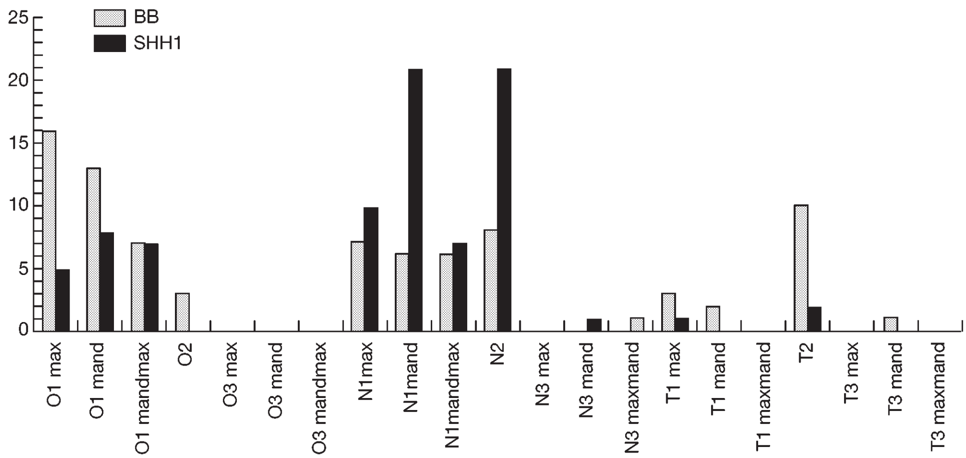

Figure 5 Distribution of the configurations according to the BB and the SHH1. The pre-treatment distributions are shown. The distributions according to the SHH2 are briefly mentioned in the text. Note the large number of patients in the open configurations according to the BB, as opposed to the SHH1, where the configurations N1mand and N2 represent the largest groups.

The distribution of the SHH2 was comparable with the BB. Within the open bite configurations of the SHH2, the largest group was the O1mand subgroup.

Comparison of the distributions of the pre-treatment skeletal configurations (T1) between the groups with open and normal overbite at the end of retention (T2)

Most patients with neutral configurations had a normal overbite at the end of retention in the three norms except for group N1mand of the SHH1, where a small majority had an open bite. Most patients with the configurations O1max at T2 of the SHH2 and the BB had a normal overbite at the end of retention. Patients with the configurations O1mand or O1mandmax of the BB, N1mand of the SHH1, and O1mand of the SHH2 mostly had an open bite at the end of retention. The largest differences were found for the configuration O1mand group of the SHH2 (Figures 6–8).

Student's t-tests

The overbite at T1 and at T2 was significantly smaller in the high risk groups of the three norms. For the change of overbite during treatment, no significant differences were found between the high and low risk groups of any of the configurations before treatment or after retention (Table 2).

Logistic regression analysis

The variables concerning the anamnestic data, treatment methods, and the risk group configurations of the three norms were taken as independent variables in order to predict the treatment result. In the first logistic regression analysis, the configurations of the BB and SHH1 were tested (Table 3), and in the second the BB and SHH2 were evaluated (Table 4).

According to the first analysis, the risk group configuration of the SHH1, the use of a posterior bite splint, and a removable retention appliance were significant predictors of the treatment result at the end of retention. Seventy-nine per cent of all patients were correctly classified.

According to the second analysis, the risk group configuration of the SHH2, the use of a posterior bite splint, and a removable retention appliance were significant predictors of the treatment result at the end of retention. Seventy-eight per cent of all patients were correctly classified.

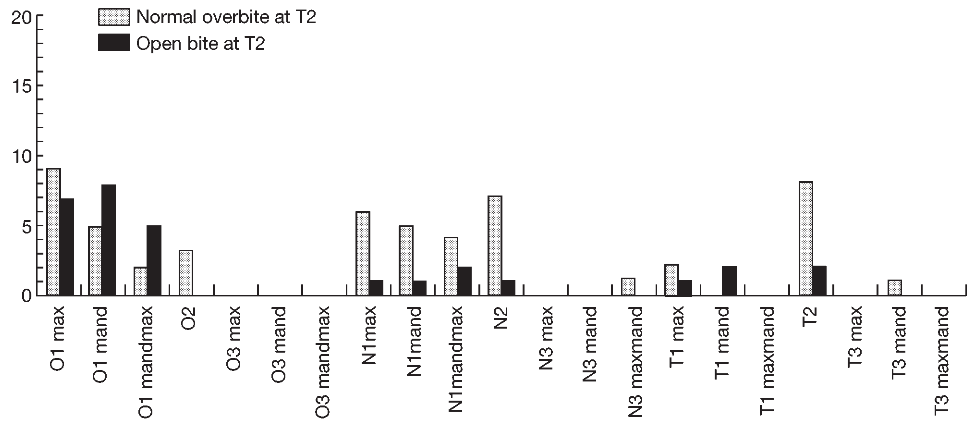

Figure 6 Distribution of the skeletal configurations at T1 between open bite and normal overbite groups at T2 according to the BB. The distribution of configurations by treatment result is shown according to the BB. Note the large number of patients with a post-treatment closed bite in the neutral and deep configurations.

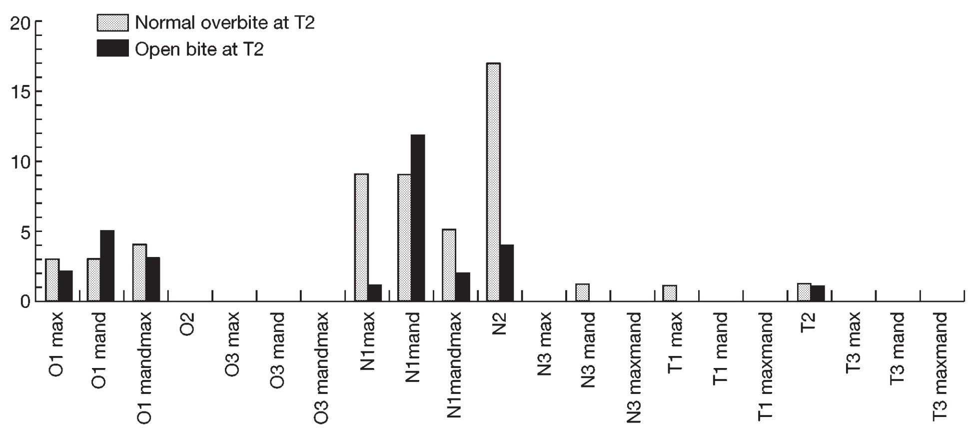

Figure 7 Distribution of the skeletal configurations at T1 between open bite and normal overbite groups at T2 according to the SHH1. The distribution of configurations by treatment result is shown according to the SHH1. Note the comparable numbers of patients with a post-treatment closed and open bite in the open configurations, and in the neutral configuration N1mand.

Discussion

The omission of patients who showed a lack of co-operation posed a risk of introducing selection bias. The subjects concerned might have shown insufficient co-operation because they felt that the treatment did not improve the dental situation. In order to minimize selection bias, a procedure was followed where patients with an open bite were selected by screening the written records concerning the orthodontic diagnosis. If an open bite was diagnosed in the written records, the pre-treatment cephalogram was examined for coincidence with the definition of an open bite used in this study. If this was the case, the written records concerning the course of the treatment were screened. If they revealed lack of co-operation and consequent treatment discontinuation, the patient was excluded regardless of

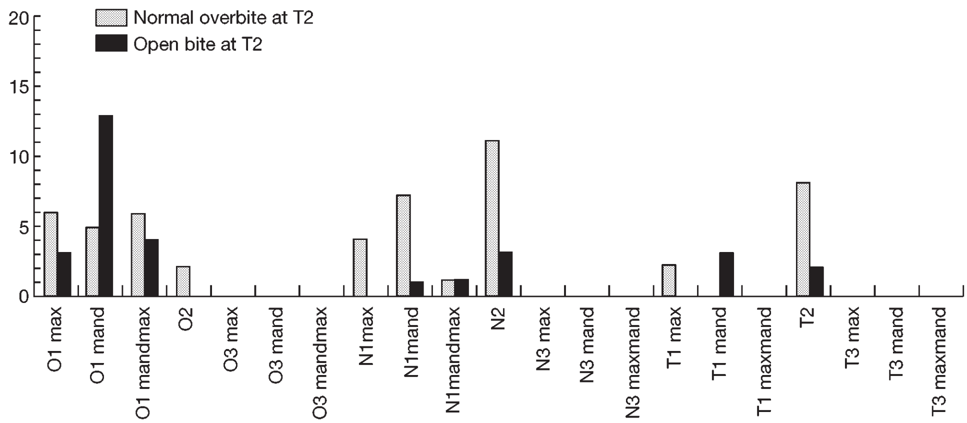

Figure 8 Distribution of the skeletal configurations at T1 between open bite and normal overbite groups at T2 according to the SHH2. The distribution of configurations by treatment result are shown according to the SHH2. Note the large numbers of patients with a post-treatment open bite in the configuration O1mand and the large majority of patients with a closed bite in the neutral configurations.

the overbite after treatment. The overbite at the end of treatment was not noted in the written records and could only be established by inspection of the cephalogram taken at the end of retention, which was not evaluated during selection. It seems probable that these patients mostly had an open bite at the end of retention, but it may also be that in some of them the overbite was increased to normal values, while other problems remained. Of course, this procedure does not fully eliminate the risk of bias, but the only alternative approach would be a prospective study.

If patients with the configurations O1mand, O1mandmax, O1max, or N1mand according to the SHH1 are considered a high risk, prediction of the overbite after retention seems to be most reliable. The results show that, within the neutral configuration N1mand of the SHH1, most patients had an open bite at the end of retention. This may indicate that the index (Figure 3) is not related to overbite. However, the values specified

Table 2 Differences between 'high' and 'low' risk groups at T1, tested with Student's *t*-tests.

	'Low risk'		'High risk'		
	Mean	SD	Mean	SD	*t*
BB	*n* = 41		*n* = 42		
Overbite T1	–1.96	0.92	–2.94	1.87	3.07**
Overbite T2	0.89	2.26	–0.24	2.47	2.17*
Overbite ΔT1–T2	2.85	2.37	2.71	2.48	0.27
SHH1	*n* = 42		*n* = 41		
Overbite T1	–2.05	1.05	–2.88	1.85	2.51*
Overbite T2	1.06	2.05	–0.43	2.56	2.94**
Overbite ΔT1–T2	3.11	2.25	2.44	2.55	1.25
SHH2	*n* = 55		*n* = 28		
Overbite T1	–1.95	1.01	–3.44	1.92	3.84***
Overbite T2	0.94	2.09	–0.89	2.61	3.45**
Overbite ΔT1–T2	2.89	2.34	2.56	2.58	0.59

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 3 Results of logistic regression analysis.

Variable	B	*P*	R	Exp (B)	–2log likelihood
Constant	–0.230	0.436			108.605
Risk group config. SHH1	0.772	0.006	0.229	2.164	97.519
Posterior bite splint	0.805	0.005	0.232	2.237	88.126
Removable retention appliance	–0.621	0.026	–0.164	0.537	83.059

Dependent variable: treatment result; independent variable: risk group configurations BB, SHH1, anamnestic data, and treatment methods.

Classification results

	Predicted outcome at T2		
Actual group T2	Normal overbite (*n*)	Open bite (*n*)	Percentage correctly classified
Normal overbite	46	7	86.79
Open bite	10	20	66.67
Percentage correctly predicted	82.1	74.1	
Overall (per cent)	79.52		

Table 4 Results of logistic regression analysis.

Variable	B	*P*	R	Exp (B)	–2log likelihood
Constant	–0.045	0.120			108.605
Risk group config. SHH2	0.624	0.022	0.172	1.866	97.674
Posterior bite splint	0.707	0.011	0.204	2.028	90.577
Removable retention appliance	–0.572	0.037	–0.147	0.565	86.172

Dependent variable: treatment result; independent variable: risk group configurations BB, SHH2, anamnestic data and treatment methods.

Classification results

	Predicted outcome at T2		
Actual group T2	Normal overbite (*n*)	Open bite (*n*)	Percentage correctly classified
Normal overbite	47	6	88.68
Open bite	12	18	60.00
Percentage correctly predicted	79.7	75.0	
Overall (per cent)	78.31		

in the literature for the upper/lower face height ratio in open or deep bite cases differ from those of the SHH1. Mean values for the proportion upper/lower face height in a normal population are 79–80 (Subtelny and Sakuda, 1964; Bishara, 1981; Fields *et al.*, 1984; Love *et al.*, 1990; Foley and Mamandras, 1992; Ligthelm-Bakker *et al.*, 1992; Segner and Hasund, 1998). Mean values for deep bite groups are generally between 81 and 87 (Nanda, 1988; Nanda and Rowe, 1989), while those for open bite groups are between 66 and 72 (Hapak, 1964; Subtelny and Sakuda, 1964; Fields *et al.*, 1984; Lopez-Gavito *et al.*, 1985; Dung and Smith, 1988; Nanda, 1988; Nanda and Rowe, 1989). It may be that most patients with the configuration N1mand of the SHH1 and with an open bite after retention mostly fall into an open bite configuration according to the criteria of the literature. Therefore, an alternative classification is proposed in this study (the SHH2), using threshold values for the index, which are set closer towards the mean value of patients with neutral configurations and are comparable with those in the literature. The SHH2 limits the high risk group to patients with open configurations O1mand and O1mandmax. The results show that the majority of patients with neutral configurations according to the BB and the SHH2 (including the configuration N1mand) had a normal overbite at T2. Therefore, it seems likely that the index also has a relationship with overbite.

The predictive values of the SHH2 are somewhat smaller compared with the SHH1, while the BB is least useful in determining high or low risk patients. If the configurations are evaluated regardless of treatment methods or other anamnestic data, determination of the low risk group seems to be more reliable than for the high risk group; the latter being most reliably predicted when using the SHH2. Consequently, if a patient does not show hyperdivergence of the mandibular plane angle at T1, a normal overbite at the end of retention may be more probable. Success in increasing the overbite cannot be guaranteed by evaluating cephalograms only, but failure can be eliminated with more certainty.

The BB has the lowest reliability. This is due to the fact that prediction of the high risk group is least reliable; the open configurations have an equally large number of patients with either open or normal overbite after treatment. In the BB, the classification O1max showed a substantial number of patients with an open bite at the end of treatment. This may be due to the fact that in the lower parts of the BB, given a fixed value for the NSBa angle, the normal value of the NL–NSL is approximately 3.5 degrees higher compared with the lower parts of the SHH1 and SHH2, whereas the norm value for ML–NSL is 9 degrees higher. In the higher parts of the box, this discrepancy is smaller for NL–NSL and ML–NSL. Mostly, the values for the angle NL–NSL are positioned in the lowest parts of the box and will wrongly classify a patient into a max subgroup, whereas in the SHH1 and SHH2, the same patient would be classified into a mand or mandmax subgroup. This may result in the large error in the high risk group.

It appears that the index, as well as the inclination of the mandible is important as predictor variables. This is reflected by the fact that only very few patients belonging to hypodivergent subgroups were found in this sample and only a few had deep bite configurations (as defined by the index).

Associations between skeletal configuration and overbite have been reported (Fleming, 1961) and are also shown in this study. However, the dimensions of the alveolar structures may weaken the correlations between the overbite and skeletal configuration. Tongue-thrusting or sucking habits may have a shortening effect upon the alveoli (Subtelny and Sakuda, 1964). Patients with a skeletal open bite configuration without sucking habits or other functional disorders may have distorted alveolar bone, which compensates for the basal skeletal morphology and maintains a normal overbite. This has been described by Solow (1980) as the dentoalveolar compensatory mechanism. These factors may be associated with the overall error of 25 per cent found in this study when the overbite was predicted with the SHH2. The fact that neutral configurations were classified correctly more often than open bite configurations suggests that in neutral configurations of the SHH2 the skeletal configuration favoured deepening of the bite during treatment and that the habits did not have a significant impact. In the open bite configurations the dentoalveolar compensatory mechanism may have counteracted the unfavourable skeletal morphology. Furthermore, incorrect classification may be associated with tongue dysfunctions, which can lead to unsuccessful treatment although the skeletal configuration is favourable.

If a removable appliance was worn during retention, a tendency towards a deeper overbite at the end of retention was observed. Most patients had worn a removable Hawley appliance, which may have permitted some active tooth movement, and retrusion of the anterior teeth may also have taken place during retention. These movements may help in stabilizing the treatment result and in increasing the overbite. The use of a posterior bite splint was associated with a tendency towards an open bite at the end of retention. The posterior bite splint is generally believed to enhance passive extrusion of the incisors and to restrain eruption of the molars (Schulze, 1978; Kiliaridis *et al.*, 1990). With this appliance, occlusal contact is present in the molar region only; thus, the anterior teeth can erupt spontaneously. The activity of the peri-oral muscles may exert additional bite closure by enhancing an anterior rotation of the mandible (Schulze, 1978). The mandible then rotates in an anterior direction while the most distal occlusal contact point of the dentition acts as a hypomochlion (Schulze, 1978). In this study the opposite effect seems to have taken place. Kiliaridis *et al.* (1990) compared two groups of open bite patients; the first group treated with a passive posterior bite splint, and the second with a bite splint with repelling magnets. In both groups, the anterior facial dimensions were reduced. However, in the group treated with a passive posterior bite splint, a rapid decrease in the effectiveness of the splint was observed. According to the authors, this may have been due to the fact that the posterior bite splint increases the lower face height. The results of this investigation support this conclusion, as in this study, a bite opening effect was observed. The bite block may stretch the muscle matrix, thus enlarging the freeway space. If the bite block is worn for approximately 14 hours a day, the molar teeth may have the opportunity to extrude during the period in which the appliance is not worn, which will increase lower face height and may contribute to the harmful effect of the posterior bite splint. In the study of Kiliaridis *et al.* (1990), the patients were followed for a period of six months, while in this investigation, the observation time was longer. Thus, the study of Kiliaridis *et al.* (1990) did not reveal any long-term effect of the posterior bite splint. They also observed a bite closing effect if the posterior bite splint was modified by the use of repelling magnets. These results would seem to indicate that active intrusion of the posterior teeth could compensate for an elongation of the muscle matrix and thus create a more stable bite closing effect.

Predictability of the high risk group was increased when evaluating the treatment and retention methods. The results suggest that a removable Hawley appliance may be especially helpful in high risk cases, while the use of a posterior bite splint for the normalization of the overbite may be more harmful in high than in low risk patients. However, since in this study no selection or further analyses of the appliances used were carried out, the findings concerning the influence of treatment methods should be interpreted with caution.

The size of the sample did not allow for a further subdivision into groups with varying overbite. However, the range of the overbite in the group with a normal overbite at T2 was between 0 and 4.7 mm. As Kim (1974) considered an overbite being between 0.5 and 4.5 mm as normal, this nomenclature could be safely used.

The results of this study raise the question as to whether the SHH box system can also be applied to predict treatment results of deep bite patients. Future studies should also include an analysis of the same patients several years after retention.

Conclusions

Open bite patients with a non-divergent skeletal pattern and a normal lower face height according to the Segner–Hasund Harmonybox classification are likely to obtain a normal overbite after treatment. The treatment result of open bite patients with a long face divergent pattern is difficult to predict. A successful treatment outcome may be enhanced by using a removable Hawley retainer during retention, which helps in closing the bite through retrusion of the upper incisors. Any inter-occlusal appliances should be avoided during treatment, as these may increase the free-way space, thus allowing the molars to extrude during the time the appliance is not worn.

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