ORIGINAL ARTICLE

Treatment results and long-term stability of anterior open bite malocclusion

D Remmers
RWGJ Van't Hullenaar
EM Bronkhorst
SJ Bergé
C Katsaros

Authors' affiliations:
Diego Remmers,
Ron WGJ Van't *Hullenaar,*
Christos Katsaros,
Department of Orthodontics and Oral Biology, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
Ewald M. Bronkhorst,
Department of Preventive and Curative Dentistry, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands
Stefaan J. Bergé, Department of Oral and Maxillofacial Surgery, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands

Correspondence to:
Christos Katsaros
Department of Orthodontics and Oral Biology
Radboud University Nijmegen Medical Centre
PO Box 9101, 6500 HB Nijmegen
The Netherlands
E-mail: orthodontics@dent.umcn.nl

Dates:
Accepted 7 October 2007

To cite this article:
Remmers D, Van't Hullenaar RWGJ, Bronkhorst EM, Bergé SJ, Katsaros C: Treatment results and long-term stability of anterior open bite malocclusion
Orthod Craniofac Res 2008;**11**:32–42

Structured Abstract

Authors – Remmers D, Van't Hullenaar RWGJ, Bronkhorst EM, Bergé SJ, Katsaros C

Objectives – To evaluate treatment results and long-term stability of anterior open bite malocclusion and to identify predictive factors for both treatment results and their stability.

Design – Retrospective study.

Setting and Sample Population – The Department of Orthodontics and Oral Biology at the Radboud University Nijmegen Medical Centre, The Netherlands. Fifty-two patients with an anterior open bite.

Methods – Lateral cephalograms and dental casts were analysed at: start of treatment (Ts), end of treatment (T0), 2 and at least 5 years after the end of treatment (T2 and T5, respectively). A standard cephalometric analysis was performed, while the Peer Assessment Rating (PAR) index was used to evaluate the occlusion.

Results – The mean PAR reduction at T0 was 74%, but decreased to 56% at T5. The mean overbite (OB) increased from −3.2 mm (± 1.9) at Ts to 0.4 mm (± 1.1) at T0, 0.1 mm (± 1.6) at T2 and 0.2 mm (± 1.8) at T5. Thirty-seven patients (71%) had a positive OB at T0, but the bite opened again in 10 of these patients (27%) from T0 to T5. Forty-four per cent of our patients had an open bite at T5. No pre-treatment variables could predict these changes.

Conclusion – Treatment response and long-term stability of the anterior open bite was found to be rather poor. This has to be taken into consideration when planning treatment of open bite patients. Prediction of open bite closure at the end of active treatment or at the follow-up was not possible.

Key words: open bite; orthodontics; retention; stability; treatment

Introduction

Although many studies (mainly case reports) describing treatment methods of anterior open bite malocclusion can be found in the orthodontic literature, only a few studies have been carried out to evaluate the long-term stability of this malocclusion (1, 2). The first study on long-term stability of the anterior open bite based on a group of patients was by Lopez-Gavito et al. (3). They found relapse in more than 35% of the treated open bite patients at the follow-up control at least 9.5 years post-retention. Although this study evaluated a quite large group of patients (n = 41) after an extensive post-retention period,

the definition of anterior open bite makes interpretation of the results difficult (4, 5). The two studies that followed (4, 5) showed a reasonable success rate (88% and 75%, respectively) and impressive stability: none of the successfully treated patients had negative overbite (OB) at the end of the post-treatment period. Both studies have, however, relatively small groups with a short post-retention period for a number of patients. Kim et al. (6) evaluated the treatment effects of the multiloop edgewise archwire therapy on open bite correction in a group of 55 patients. This study showed an impressive stability at the end of the 2-year follow-up period. However, the results of this study might have been strongly influenced by the fact that post-retention records were missing in more than 50% of the patients. The treatment effect of a modification of Kim et al.'s technique was studied in a group of 17 patients (7). In 10 of these patients, where records were available 1 year post-retention, a decrease of OB from 1.75 to 0.5 mm was observed during the post-retention period. No information on how many of these patients had an open bite at the 1-year follow-up could be found. The small size of the patient group with follow-up records and the short follow-up period do not allow safe conclusions to be drawn. During the last years, the stability of treatment results in two groups of open bite patients from Brazil has been presented (8–10). One group was treated with extractions (n = 31) and had follow-up records at least 5 years after treatment, while the other (n = 21) was treated without extractions and had follow-up records at least 3 years after treatment. Differently from the earlier studies, these publications reported high relapse rates (25.8% of the patients in the extraction group and 38.1% of the patients in the non-extraction group had an open bite at the follow-up).

The small number of studies on the stability of orthodontic treatment results of the anterior open bite, the limitations in several of them (small size groups, short post-treatment period, loss of records to follow-up, problematic definition) and the considerably contradictory results have arisen the need to carry out more studies in this area. Furthermore, most of the studies are purely cephalometric, they concentrate mainly on the closure or not of the open bite and do not perform an evaluation of the general occlusal outcome. Therefore, the aims of the present study were to evaluate treatment results and long-term stability of anterior open bite malocclusion in a large group of patients, and to identify predictive factors for both treatment results and their stability.

Subjects and methods

Subjects

Patients were selected from the archives of the Department of Orthodontics and Oral Biology, Radboud University Nijmegen Medical Centre, The Netherlands. Our group of patients treated between 1970 and 1992 was selected according to the following criteria:

1 Presence of a pre-treatment (Ts) OB of less than 0 mm according to the following definition; anterior open bite is the absence of vertical overlap of the incisor edges of the maxillary and mandibular incisors relative to the Nasion–Menton (N–Me) line (Fig. 1).
2 Comprehensive orthodontic treatment.
3 No surgical treatment or re-treatment.
4 Caucasian.
5 No cleft lip and palate or craniofacial anomalies.
6 Lateral cephalograms and dental casts at Ts, T0, T2 and T5 must be available.
7 No prosthetic replacement or prosthetic treatment in the incisal region.

Fifty-two patients (17 males, 35 females) fulfilled these criteria and were included in this study. All patients were treated with full fixed appliances (edgewise), while high-pull headgear or functional appliances were additionally used in a number of patients.

Methods

Evaluation of the occlusion

The PAR index, as described by Richmond et al. (11) was applied on all dental casts at Ts, T0, T2 and T5 to evaluate the occlusal outcome of treatment with time. Scores were assigned to various occlusal traits of the malocclusion. The components scored in the PAR index are: alignment of upper anterior segments, alignment of lower anterior segments, left buccal occlusion, right buccal occlusion, overjet, OB, centreline. The individual scores for overjet are multiplied by

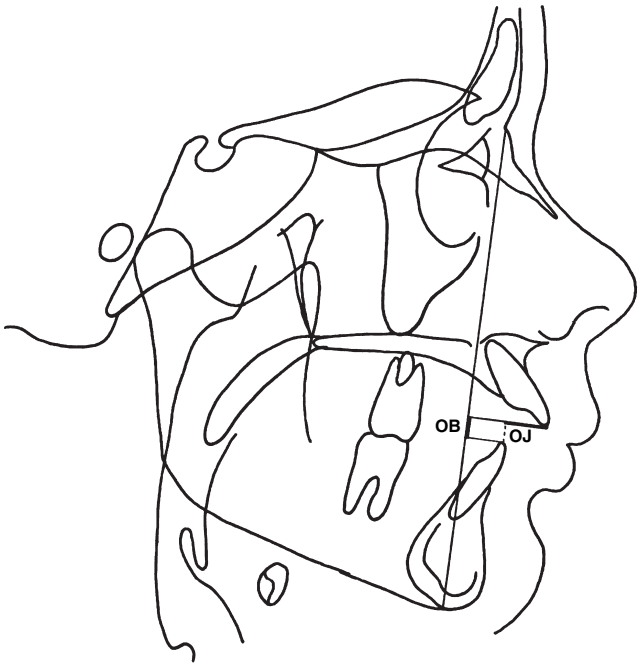

Fig. 1. Overjet (OJ) and OB as measured in the present study.

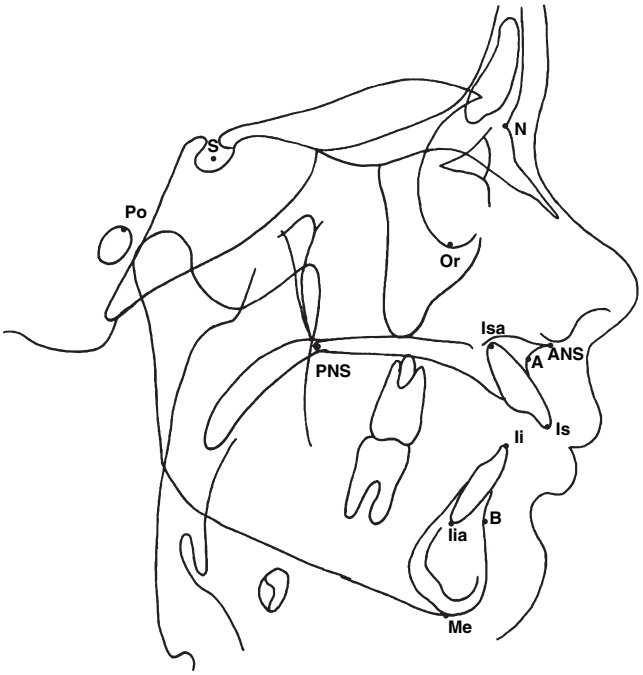

Fig. 2. Cephalometric points used in the present study.

6, scores for OB by 2 and the scores for centreline by 4 (British weighting system). The individual scores are summed to obtain a total that represents the degree to which a case deviates from normal alignment and occlusion. A score of zero indicates good alignment and occlusion and higher scores indicate increased levels of irregularity and/or malocclusion.

The difference between the Ts PAR scores and T0 PAR scores indicates the degree of improvement as a result of the orthodontic treatment. The difference between T0 PAR scores and the T2 or T5 PAR scores indicates the degree of increase or decrease of the malocclusion during the post-treatment period. To illustrate the degree of improvement between Ts PAR score and T0 PAR score as well as between Ts PAR score and T5 PAR score nomograms were used. In a nomogram, the degree of change is divided in three sections: worse or no difference (patients showing less than 30% reduction in PAR score), improved (patients showing greater or equal to 30% reduction in PAR score) and greatly improved (generally a reduction of 22 weighted PAR points or more).

Cephalometric analysis

All cephalograms for all treatment stages were made with the same cephalostat with the lips of the patient in rest position and the teeth in maximum occlusion. The focus-film distance was 5.04 m and an intensifying screen was used. Since the magnification was constant, no correction was applied on the linear measurements. All cephalometric radiographs were scanned with a flatbed scanner (Linotype-Hell, Eschborn, Germany) at 150 dpi. The cephalograms were traced and analysed on the computer with Viewbox 3.00 (dHal Software, Athens, Greece). The cephalometric points and lines used in this study are shown in Figs. 2 and 3, respectively. Table 1 presents the definitions of the cephalometric points, Table 2 the used cephalometric lines and Table 3 the performed cephalometric measurements used in this study.

Measurement error

To assess inter-observer agreement, cephalograms and dental casts of 19 patients were measured by a second observer. For all variables, paired *t*-tests were performed to look for systematic differences. The random error was calculated as the SD in the differences divided by the square root of 2. The reliability coefficient is equal to the Pearson's correlation coefficient between the measurements of both observers. For the OB value, when used as a dichotomous variable in the logistic regression analysis, the kappa statistic was used to calculate the level of inter-observer agreement.

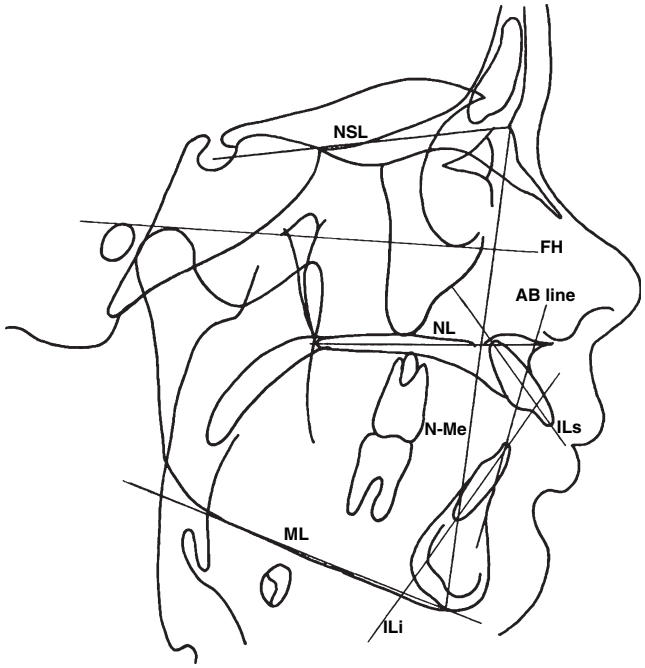

Fig. 3. Cephalometric lines used in the present study.

Statistical analysis

Descriptive statistics were calculated. To explain closure/opening of the bite logistic regression analyses were applied, using the dichotomized OB variable (using 0 as cut-off value) as dependent variable and all consecutive cephalometric variables as independent variables.

Statistical significance was considered to have reached at a level of $p = 0.05$. The ± sign is used to indicate SD.

The nomogram was used to illustrate the degree of improvement in the PAR index.

Results

Measurement error

Table 4 shows the inter-observer agreement for the cephalometric measurements and PAR index. For six cephalometric variables (SNA, SNB, ANB, ML/NSL, ML/NL and ODI; Table 3) and for the PAR score, a statistically significant difference between the two observers was found. However, for all of these variables, the random error was small in comparison with the SD of the measurement (see Tables 4 and 5 and Fig. 4). The inter-observer agreement for the OB variable as expressed by the kappa statistics was 0.430. This is considered to be 'moderate' (12).

Background and baseline variables

The mean age of the patients was: 12.4 years (± 2.7) at Ts, 15.8 years (± 2.7) at T0, 17.9 years (± 2.8) at T2 and 24.1 years (± 3.5) at T5. The mean treatment time was 3.4 years (± 1.3). The mean difference between T0 and

Table 1. **Definitions of the cephalometric points used in the present study (Fig. 2)**

Nasion (N)	The most anterior point of the naso-frontal suture
Sella (S)	The centre of sella turcica
A-point (A)	The deepest point on the premaxilla, between the anterior nasal spine and the dental alveolus
B-point (B)	The deepest point on the contour of the mandible between infradentale and pogonion
Anterior nasal spine (ANS)	The tip of the anterior nasal spine
Posterior nasal spine (PNS)	The tip of the posterior nasal spine
Menton (Me)	The lowest point on the inferior border of the mandibular symphysis
Incision superius (Is)	The incisal tip of the most anterior upper incisor
Incision superius-apex (Isa)	The root tip of the most anterior upper incisor
Incision inferius (Ii)	The incisal tip of the most anterior lower incisor
Incision inferius-apex (Iia)	The root tip of the most anterior lower incisor
Orbitale (Or)	The lowest point in the inferior margin of the orbit
Porion (Po)	The superior point of the external auditory meatus

Table 2. **Definitions of reference lines used in the present study (Fig. 3)**

Nasion-Sella line (NSL)	The line through Sella (S) and Nasion (N)
Nasal line (NL)	The line through anterior (ANS) and posterior (PNS) nasal spine
Mandibular line (ML)	The tangent from Menton (Me) to the most inferior point of the gonial region of the mandible
Nasion-Menton line (N-Me)	The line through Nasion (N) and Menton (Me)
Incisal line superius(ILs)	The line through Incision superius (Is) and Incision superius-apex (Isa) – the long axis of the upper incisor
Incisal line inferius (ILi)	The line through Incision inferius (Ii) and Incision inferius-apex (Iia) – the long axis of the lower incisor
AB line (AB)	The line through A-point and B-point
Frankfurt Horizontal (FH)	The line through Porion (Po) and Orbitale (Or)

Table 3. **Cephalometric measurements used in the present study**

SNA	The angle between the Nasion–Sella line (NSL) and the line connecting Nasion (N) and A-point (A)
SNB	The angle between the Nasion–Sella line (NSL) and the line connecting Nasion (N) and B-point (B)
ANB	The difference between the angles SNA and SNB
ML/NL	The angle between the mandibular line (ML) and the nasal line (NL)
ML/NSL	The angle between the mandibular line (ML) and the Nasion-Sella line (NSL)
NL/NSL	The angle between the Nasion-Sella line (NSL) and the Nasal line (NL)
ILs/ILi	The angle formed by the long axis of the upper and lower incisors (Inter-incisal angle)
ILs/NSL	The angle between the long axis of the upper incisor (ILs) and the Nasion-Sella line (NSL)
ILi/ML	The angle formed by the long axis of the lower incisor (ILi) and the mandibular line (ML)
OB	Overbite, the distance between the perpendiculars from the incisal edges of the upper and lower incisors to the N–Me line. A frontal open bite was recorded as a negative value; incisal overlap starting with the value 0 was recorded as a positive value.
OJ	Overjet; the distance from Incision superius to the parallel to the N–Me line passing through Incision inferius (Ii)
ODI	Overbite depth indicator: the arithmetic sum of the angle formed by the AB line and the mandibular line (ML) and the angle formed by the Nasal line (NL) and the Frankfurt Horizontal (FH).

T2 was 2.1 years (± 0.3). The mean difference between T5 and T0 was 8.3 years (± 2.9). Extraction therapy was applied in 17 patients (4 upper arch extractions only, 13 upper and lower arch extractions).

PAR score

The mean PAR scores at the four registration stages can be seen in Fig. 4. The mean reduction in the PAR score was 74% at T0, but decreased to 56% at T5. The nomogram for the period Ts–T0 is shown in Fig. 5. Three patients (6%) fell in the worse or no difference group, 10 patients (19%) in the improved group and 39 patients (75%) in the greatly improved group. The nomogram for the period Ts–T5 is shown in Fig. 6. Thirteen patients (25%) fell in the worse or no difference group, 13 patients (25%) in the improved group and 26 patients (50%) in the greatly improved group.

Cephalometric variables

The pre-treatment cephalometric values indicate a sample consisting of subjects with high mandibular plane angle and a Class II skeletal tendency. Table 5 shows the descriptive statistics for the cephalometric variables. The mean OB increased from −3.2 mm (± 1.9) at Ts to 0.4 mm (± 1.1) at T0, 0.1 mm (± 1.6) at T2 and 0.2 mm (± 1.8) at T5. The mean overjet

Table 4. **Inter-observer agreement (n = 19). Paired *t*-test for systematic error and *p*-value. Reliability is calculated as the Pearson's correlation coefficient. Random error is SD in differences divided by √2**

Variable	Systematic error	*p*-value	Reliability	Random error
SNA (°)	1.5	0.000	0.86	1.5
SNB (°)	0.5	0.026	0.93	1.0
ANB (°)	1.0	0.000	0.83	1.0
ML/NL (°)	0.8	0.037	0.90	1.7
ML/NSL (°)	0.9	0.012	0.92	1.6
NL/NSL (°)	0.1	0.716	0.67	1.6
ILs/ILi (°)	−1.0	0.090	0.91	2.5
ILs/NSL (°)	0.7	0.102	0.85	1.9
ILi/ML (°)	−0.7	0.216	0.93	2.3
OJ (mm)	0.1	0.212	0.99	0.2
OB (mm)	0.1	0.225	0.97	0.2
ODI	2.1	0.000	0.90	2.4

decreased from 7.3 mm (± 2.6) at Ts to 3.3 mm (± 1.4) and remained rather stable during the post-treatment period. The sagittal and vertical jaw relationships did not change significantly during the observation period. Both upper and lower incisors have been on the average retroclined with treatment.

Closure of the anterior open bite and re-opening

Figure 7 shows the development of the OB at the different stages. Thirty-seven patients (71% of the total sample) had a positive OB at the end of treatment (T0). Six of these patients presented a negative OB at T2, while another four of these patients presented a negative OB at T5. Thus, from the 37 patients who had a positive OB at the end of treatment, 10 patients relapsed in the period from T0 to T5 and showed a negative OB. On the other hand, from the 15 patients

Table 5. **Descriptive statistics (mean, SD) for the cephalometric variables (n = 52)**

Variable		Ts	T0	T2	T5	T0–Ts	T5–Ts	T2–T0	T5–T0	T5–T2
SNA (°)	Mean	79.9	79.2	79.3	79.2	−0.6	−0.7	0.0	0.0	0.0
	SD	4.3	4.3	4.2	4.3	1.0	1.5	0.6	1.1	0.8
SNB (°)	Mean	75.0	75.6	75.8	76.0	0.5	1.0	0.2	0.5	0.2
	SD	3.3	3.4	3.5	3.7	1.1	1.7	0.7	1.2	0.9
ANB (°)	Mean	4.8	3.7	3.4	3.2	−1.2	−1.7	−0.2	−0.5	−0.2
	SD	2.3	2.2	2.2	2.5	1.5	1.8	0.9	1.2	0.9
ML/NL (°)	Mean	34.4	33.6	33.7	33.6	−0.9	−0.8	0.2	0.1	−0.1
	SD	6.0	6.4	6.3	6.5	3.0	3.7	2.2	2.8	2.2
ML/NSL (°)	Mean	40.9	40.6	40.5	40.3	−0.3	−0.6	−0.1	−0.3	-0.2
	SD	6.1	6.3	6.4	6.8	2.4	3.3	2.2	2.9	2.0
NL/NSL (°)	Mean	6.5	7.0	6.8	6.6	0.6	0.2	−0.3	−0.4	-0.1
	SD	2.9	3.0	3.2	3.5	2.2	1.8	1.4	1.8	1.5
ILs/ILi (°)	Mean	118.1	127.1	125.7	125.7	9.0	7.6	−1.5	−1.4	0.1
	SD	10.3	9.5	8.2	9.5	11.0	11.1	5.6	7.7	5.0
ILs/NSL (°)	Mean	107.8	100.3	102.4	102.2	−7.5	−5.6	2.2	1.9	-0.2
	SD	6.1	7.1	5.6	5.9	7.9	7.5	4.1	5.7	3.1
ILi/ML (°)	Mean	93.2	92.0	91.4	91.8	−1.2	−1.4	−0.6	−0.2	0.4
	SD	9.6	8.5	8.3	9.4	6.4	7.1	3.5	4.3	3.5
OJ (mm)	Mean	7.3	3.3	4.0	4.0	−4.0	−3.3	0.8	0.7	0.0
	SD	2.6	1.4	1.5	1.6	2.7	3.0	1.1	1.3	0.9
OB (mm)	Mean	−3.2	0.4	0.1	0.2	3.6	3.4	−0.2	−0.1	0.1
	SD	1.9	1.1	1.6	1.8	2.1	2.3	1.1	1.4	0.7
ODI	Mean	70.6	70.4	69.6	68.7	−0.2	−1.9	−0.8	−1.7	−0.9
	SD	7.5	7.4	7.0	7.3	3.7	4.1	3.0	3.7	2.5

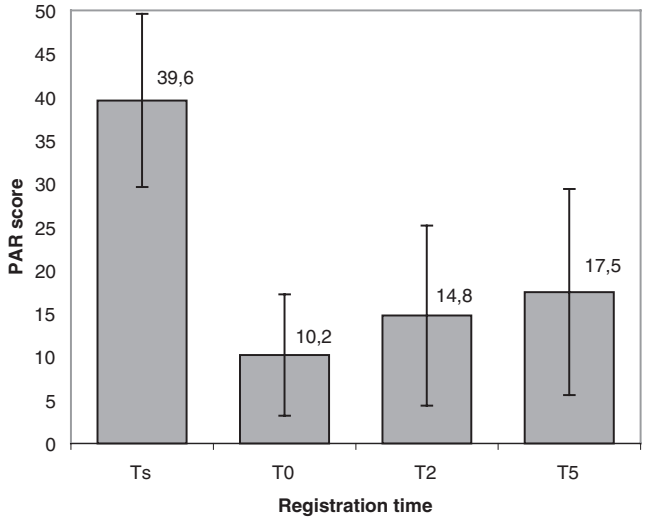

Fig. 4. Mean Peer Assessment Rating (PAR) ± SD scores at the four registration stages (n = 52). Ts, start of treatment; T0, end of treatment; T2, 2 years after the end of treatment; T5, at least 5 years after the end of treatment.

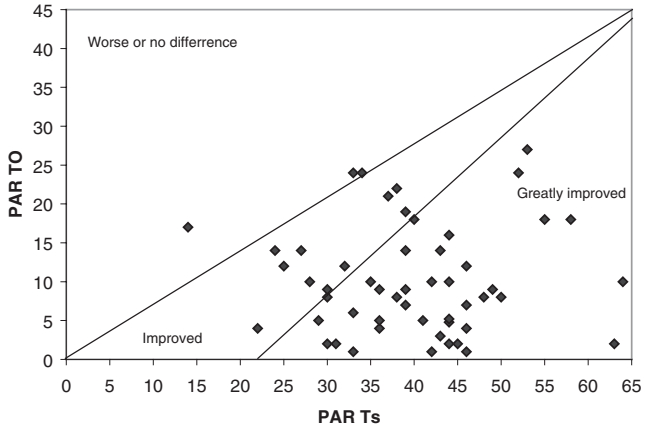

Fig. 5. Nomogram with Peer Assessment Rating (PAR) score at the start of treatment (Ts) as compared to the PAR score at the end of treatment (T0). Note that 94% of the patients fell in the 'Improved' and 'Greatly improved' categories and that only 6% of the patients fell in the 'Worse or No difference' category.

(29% of the total sample) who had a negative OB also at the end of treatment (T0), two patients showed a spontaneous closure of the bite at T2 that remained stable at T5. Twenty-three patients (44%) in our sample had an open bite at T5.

Prediction of closure

Twenty-four logistic regression models were applied (Table 6). Two times, a significant relation between presence of open bite at T5 and a pre-treatment cephalometric variable (ML/NL and ML/NSL) was

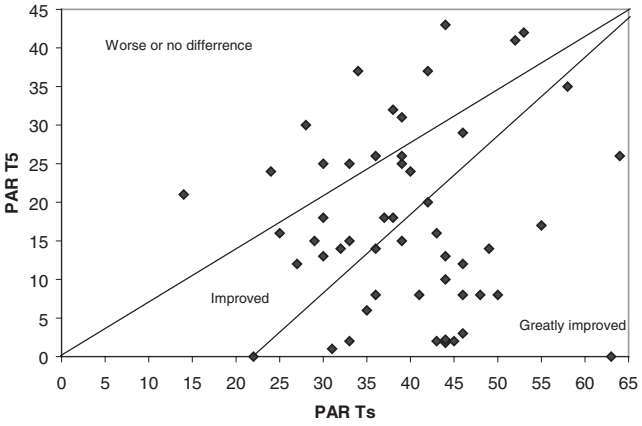

Fig. 6. Nomogram with Peer Assessment Rating (PAR) score at the start of treatment (Ts) as compared to the PAR score at least 5 years after the end of treatment (T5). Note that 25% of the patients fell in the 'Worse or No difference' category because of post-treatment changes.

found. These two variables were highly correlated (r = 0.88). Also extraction therapy (upper arch, both arches, non-extraction) was not associated with the closure of the anterior open bite neither at T0 nor at T5 (Table 7).

Discussion

This study evaluated the treatment results and long-term stability of open bite patients, based on occlusion and cephalometric changes. Although most publications report the intra-observer error, which is usually smaller than the inter-observer error, we have chosen to analyse the inter-observer error for all cephalometric variables and the PAR score. The reason for that was that the intra-observer error cannot detect systematic errors. For six of the cephalometric variables and PAR score, a systematic difference between the observers was found. However, for all these variables the systematic difference between the observers was small, much smaller than the SD of the specific variable. As the variability induced by the measurement error was so small, we decided to include these variables in the analysis.

In the present study, the average PAR score at the beginning of treatment was very high. Fifty-one of the 52 patients had an initial score of ≥22 points. The PAR reduction with treatment was 74%. Only three patients (6%) fell in the 'worse or no difference' category after treatment, while 75% of the patients could be

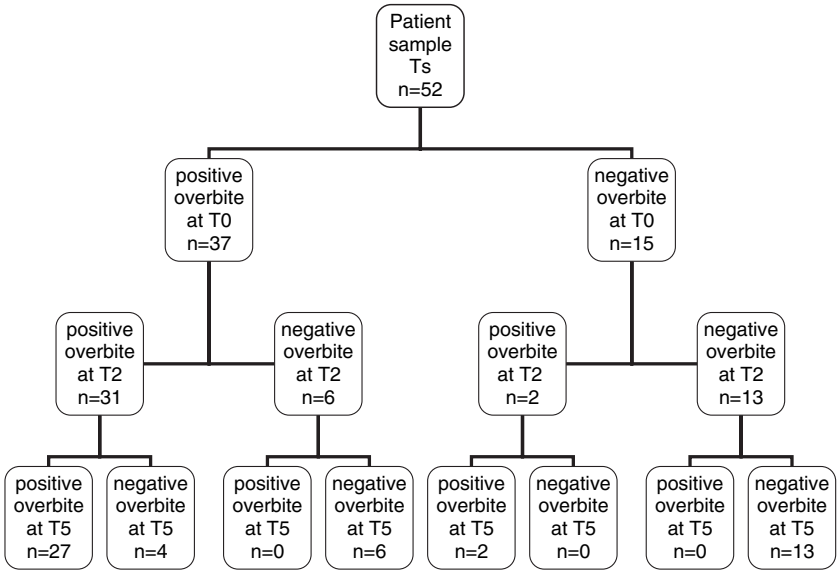

Fig. 7. Number of patients with positive or negative OBs at the different registration stages. Ts, start of treatment; T0, end of treatment; T2, 2 years after the end of treatment; T5, at least 5 years after the end of treatment.

categorized as 'greatly improved'. A 70% reduction of the PAR score is considered a great improvement of the occlusion (11, 13). The PAR reduction in our sample was comparable to the reduction reported in one British and one Norwegian sample with a general spectrum of malocclusions (68% and 78% reduction in PAR score, respectively). It was, however, lower than the 88% reduction in PAR score, in a selected sample of American Board of Orthodontists patients (14–16). At the follow-up, for at least 5 years post-treatment, the PAR reduction decreased to 56% because of the post-treatment changes in occlusion. Twenty-five per cent of the patients fell in the 'worse or no difference' category, which means that these patients presented an increased degree of malocclusion at the follow-up. The fact that OB has a weighting of 2 in the British weighting system further worsens the PAR reduction post-treatment.

If treatment success is judged by the achievement of a positive OB at the end of treatment, 71% of our patients were successfully treated. In 29% of the patients, a positive OB could not be reached, although an improvement of the open bite took place. The studies of Huang et al. (4) and Katsaros & Berg (5) showed a somewhat bigger success rate (88 and 75% of their patients respectively had a positive OB at the end of treatment). The latter two studies, however, strongly differ from the present study as regards stability of the treatment results. They reported an impressive stability, as none of the successfully treated patients had negative OB at the end of the post-treatment period. On the other hand, 27% of the patients in the present study where a positive OB could be reached at the end of treatment, showed relapse of the open bite in the period of T0–T5. If we take into account also the patients where a positive OB could not be achieved with orthodontic treatment, 44% of our patients had an open bite at T5. This large difference in stability between our study and the studies of Huang et al. (4) and Katsaros & Berg (5) might be attributed to rather small patient groups (which might denote possible selection bias) in the latter studies, as well as in the fact that their post-treatment period was short for a number of patients. As the present study showed a positive OB can remain stable for 2 years after the end of treatment (T2) and relapse during the subsequent period. The study of Kim et al. (6) was the only one that showed a 100% treatment success and an almost 100% stability. However, the results of this study might have been strongly influenced by the fact that post-retention records were missing in more than 50% of the patients. The Brazilian studies (8–10) showed also relatively high relapse of the open bite at the follow-up control. In the extraction group, 25.8% of the patient sample presented again an open bite after a follow-up period of at least 5 years, while in the non-extraction group, the open bite relapse was 38.1% after a follow-up period of at least 3 years. This difference between extraction and

Table 6. **Univariate logistic regression models with open bite (yes/no) at T0 and T5 as dependent variable and all cephalometric measurements at Ts as independent variable. OR indicates change in odds ratio for the chance of a bite not being closed because of the increase of the independent variable by one unit**

Variable	*p*-value	OR (95% CI)
Open bite at T0		
SNA (°)	54.9%	0.957 (0.829–1.105)
SNB (°)	64.9%	0.958 (0.795–1.154)
ANB (°)	63.2%	0.935 (0.712–1.229)
ML/NL (°)	17.1%	1.075 (0.969–1.193)
ML/NSL (°)	35.0%	1.049 (0.949–1.159)
NL/NSL (°)	37.8%	0.912 (0.742–1.120)
ILs/ILi (°)	76.1%	0.991 (0.935–1.051)
ILs/NSL (°)	70.7%	0.981 (0.889–1.083)
ILi/ML (°)	97.5%	0.999 (0.938–1.064)
OJ (mm)	87.6%	1.019 (0.804–1.291)
OB (mm)	30.1%	0.844 (0.613–1.164)
ODI	25.1%	0.952 (0.876–1.035)
Open bite at T5		
SNA (°)	25.5%	0.925 (0.809–1.058)
SNB (°)	21.1%	0.894 (0.750–1.066)
ANB (°)	73.7%	0.959 (0.750–1.225)
ML/NL (°)	3.7%	1.116 (1.007–1.238)
ML/NSL (°)	3.7%	1.117 (1.007–1.240)
NL/NSL (°)	93.0%	1.009 (0.836–1.217)
ILs/ILi (°)	80.4%	1.007 (0.954–1.062)
ILs/NSL (°)	36.1%	0.958 (0.873–1.051)
ILi/ML (°)	29.1%	0.969 (0.913–1.028)
OJ (mm)	58.7%	0.941 (0.757–1.171)
OB (mm)	23.2%	0.826 (0.603–1.130)
ODI	5.1%	0.921 (0.848–1.000)

Table 7. **Relation between extractions and closure of the open bite at T0, T2 and T5. *p*-values refer to Fisher's exact test**

	T0		T2		T5		
Extraction	Closed	Open	Closed	Open	Closed	Open	Total
None	26	9	23	12	19	16	35
Upper jaw	1	3	1	3	1	3	4
Both jaws	10	3	9	4	9	4	13
Total	37	15	33	19	29	23	52
p	0.154		0.304		0.322		

non-extraction groups led the authors to the conclusion that extraction treatment provided greater stability of the open bite correction. It must be pointed out, however, that the difference in the percentages of patients with open bite relapse was not statistically significant between the groups (10). In our patient sample, extraction therapy (upper arch, both arches, non-extraction) was not associated with the closure or stability of the anterior open bite. However, this may be a confounder by indication. In other words, what would have happened to the OB if in the extraction patients, treatment had been performed without extractions?

Also Lopez-Gavito et al. (3) found relapse in more than 35% of the treated open bite patients studied at least 9.5 years post-retention. However, the definition of anterior open bite in that study makes the comparison with our results difficult. The authors defined open bite on the pre-treatment lateral cephalogram when the linear distance from the incisal edge of the most anterior mandibular incisor to the contact point of the opposing hard-tissue structure projected along the long axis of the mandibular incisor was >3 mm. This distance, however is not always a reliable indicator of the presence of open bite malocclusion as this situation can be also found in deep bite patients with a large sagittal discrepancy (5). Nor is it a reliable criterion for open bite relapse, because changes in anteroposterior and in incisor inclination can cause this measurement to increase or decrease without corresponding changes in OB (4). Furthermore, Huang (2) reported that the sample of Lopez-Gavito et al. (3) was analysed again in an unpublished Master's thesis measuring the OB relatively to the N–Me line. The new analysis showed that all subjects had positive overlap at the follow-up control.

An interesting finding in our study was that two of the patients, where no positive OB could be achieved with treatment, showed a spontaneous closure of the bite during the post-treatment period. From the patient files, it was not possible to identify the reason. Spontaneous closure of open bite in untreated patients has been described earlier in cross-sectional studies (17, 18). However these patients are difficult to be identified (19).

One of the problems is the capability to predict the possibility of closure of the open bite; the OB depth indicator (ODI) is one of the measurements that has been proposed to be useful for that (20, 21). This study

however, could not confirm the predictive value of the ODI nor any other significant relation between any of the other variables at Ts and opening of the bite at T0 or T5. Twenty-four logistic regression models were applied. Two times a significant relation between presence of open bite at T5 and a pre-treatment variable (ML/NL and ML/NSL) was found. Performing a series of statistical analysis inevitably leads to the risk of false-positive results. In this case, after performing over 20 tests, at least one positive result is to be expected by chance alone. Here two positive results were found, but given the very high correlation between ML/NL and ML/NSL (r = 0.88), this might as well be considered as just one positive result. Combining this with the fact that for these two variables the relation with the open bite over a much smaller time frame, i.e. at T0, was not statistically significant, labelling the two positive findings as pure chance findings appears to be the best interpretation. This leads to the overall conclusion that open bite cannot be successfully predicted from the pretreatment cephalometric variables. Also previous studies (4, 22) did not find any cephalometric variable to be a predictor of treatment response and stability. Although in the present group of patients both upper and lower incisors have been on the average retroclined with treatment, this was not found to be a favourable factor for treatment prognosis as previously reported (5).

The poor treatment response between Ts and T0 in the present study raises the question whether conventional edgewise treatment can adequately control the vertical dimension. New methods like skeletal anchorage (23, 24) seem to be promising, but their effectiveness has to be confirmed with scientific data based on large patient groups. However, even if these methods can help in correcting the open bite, they probably cannot solve the problem of long-term post-treatment stability. Long-term stability of the open bite correction is not a matter of treatment method or appliance, but it is mainly influenced by growth after treatment (25) or by functional disturbances.

Our study, like the previous studies on stability of anterior open bite malocclusion is of retrospective nature and thus cannot exclude selection bias, control all treatment variables and give insight to the mechanisms of relapse. This can only be carried out with well-designed prospective trials.

In conclusion, treatment response and long-term stability of the anterior open bite was found to be rather poor. This has to be taken into consideration when planning treatment of open bite patients. Prediction of open bite closure at the end of active treatment or at the follow-up was not possible.

References

1. Katsaros C, Berg R, Kiliaridis S. Anterior open bite. In: Kuijpers-Jagtman AM, Leunisse M, editors. *Orthodontics at the Turn of the Century. Proceedings of the 10th International Orthodontic Studyweek*. Nijmegen: NVOS; 2001. pp. 65–88.
2. Huang GJ. Long-term stability of anterior open-bite therapy: a review. *Semin Orthod* 2002;8:162–72.
3. Lopez-Gavito G, Wallen TR, Little R, Joondeph DR. Anterior open-bite malocclusion: a longitudinal 10-year postretention evaluation of orthodontically treated patients. *Am J Orthod* 1985;87:175–86.
4. Huang GJ, Justus R, Kennedy DB, Kokich VG. Stability of anterior openbite treated with crib therapy. *Angle Orthod* 1990;60:17–24.
5. Katsaros C, Berg R. Anterior open bite malocclusion: a follow-up study of orthodontic treatment effects. *Eur J Orthod* 1993;15: 273–80.
6. Kim YH, Han UK, Lim DD, Serraon MLP. Stability of anterior open bite correction with multiloop edgewise archwire therapy: a cephalometric follow-up study. *Am J Orthod* 2000;118:43–54.
7. Kucukkeles N, Acar A, Demirkaya AA, Evrenol B, Enacar A. Cephalometric evaluation of open bite treatment with NiTi arch wires and anterior elastics. *Am J Orthod Dentofacial Orthop* 1999;116:555–62.
8. Janson G, Valarelli FP, Henriques JFC, De Freitas MR, Cançado RH. Stability of anterior open bite nonextraction treatment in the permanent dentition. *Am J Orthod Dentofacial Orthop* 2003;124:265–76.
9. De Freitas MR, Beltrão RTS, Janson G, Henriques JFC, Cançado RH. Long-term stability of anterior open bite extraction treatment in the permanent dentition. *Am J Orthod Dentofacial Orthop* 2004;125:78–87.
10. Janson G, Valarelli FP, Beltrão RTS, De Freitas MR, Henriques JFC. Stability of anterior open-bite extraction and nonextraction treatment in the permanent dentition. *Am J Orthod Dentofacial Orthop* 2006;129:768–74.
11. Richmond S, Shaw WC, Roberts CT, Andrews M. The PAR Index (Peer Assessment Rating): methods to determine outcome of orthodontic treatment in terms of improvement and standards. *Eur J Orthod* 1992;14:180–7.
12. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.
13. DeGuzman L, Bahiraei D, Vig KW, Vig PS, Weyant MS, O'Brien KD. The validation of the peer assessment rating index for malocclusion severity and treatment difficulty. *Am J Orthod Dentofac Orthop* 1995;107:172–6.
14. O'Brien KD, Shaw WC, Roberts CT. The use of occlusal indices in assessing the provision of orthodontic treatment by the hospital orthodontic service of England and Wales. *Br J Orthod* 1993;20:25–35.

15. Richmond S, Andrews M. Orthodontic treatment standards in Norway. *Eur J Orthod* 1993;15:7–15.
16. Dyken RA, Sadowsky PL, Hurst D. Orthodontic outcomes assessment using the peer assessment rating index. *Angle Orthod* 2001;71:164–9.
17. Adams CP. Relationship between facial growth and incisor OB. *Dent Pract Dent Rec* 1966;17:68–9.
18. Richardson A. Facial growth and the prognosis for anterior open bite – a longitudinal study. *Trans Eur Orthod Soc* 1971;47:149–57.
19. Finlay JA, Richardson A. Outcome prediction in open bite cases. *Eur J Orthod* 1995;17:519–23.
20. Kim YH. Overbite depth indicator with particular reference to anterior open-bite. *Am J Orthod* 1974;65:586–611.
21. Klocke A, Nanda RS, Kahl-Nieke B. Anterior open bite in the deciduous dentition: longitudinal follow-up and craniofacial growth considerations. *Am J Orthod* 2002;122:353–8.
22. Dung DJ, Smith RJ. Cephalometric and clinical diagnosis of open-bite tendency. *Am J Orthod Dentofacial Orthop* 1988;94:484–90.
23. Sugawara J, Baik UB, Umemori M, Takahashi I, Nagasaka H, Kawamura H et al. Treatment and posttreatment dentoalveolar changes following intrusion of mandibular molars with application of a skeletal anchorage system (SAS) for open bite correction. *Int J Adult Orthodon Orthognath Surg* 2002;17:243–53.
24. Erverdi N, Keles A, Nanda R. The use of skeletal anchorage in open bite treatment: a cephalometric evaluation. *Angle Orthod* 2004;74:381–90.
25. Nemeth RB, Isaacson RJ. Vertical anterior relapse. *Am J Orthod* 1974;65:565–85.