ORIGINAL ARTICLE

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# Cervical column morphology in patients with skeletal open bite

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**Structured Abstract**

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***Objectives –*** To examine and compare the cervical column morphology in adult patients with skeletal open bite with the cervical column morphology of an adult control group with neutral occlusion and normal craniofacial morphology.

***Design –*** A retrospective case–control study.

***Setting and Sample Population –*** Thirty-eight open bite patients, 27 women, aged 17–39 years, and 11 males, aged 18–40 years were compared with 21 controls, 15 females, aged 23–40 years, and six males aged 25–44 years from profile radiographs.

***Outcome measure –*** From each individual a visual assessment of the cervical column and angular measurements of the craniofacial dimensions were performed on profile radiographs.

***Results –*** In the open bite group 42.1% had cervical column body fusion, and 13.2% had posterior arch deficiency. The fusion always occurred between C2 and C3. Cervical column deviations occurred significantly more often in the open bite group compared with the control group ($p < 0.05$). Associations were found between fusions of the cervical column and maxillary retrognathia ($p < 0.05$), large maxillary inclination ($p < 0.05$) and large cranial base angle ($p < 0.05$). Associations were also found between posterior arch deficiency and maxillary retrognathia ($p < 0.05$) and cranial base angle ($p < 0.05$). The craniofacial parameter most important for the fusions and posterior arch deficiency was the maxillary retrognathia ($p < 0.01$, $R^2 = 0.20$; $p < 0.05$, $R^2 = 0.26$, respectively).

***Conclusion –*** New associations between skeletal open bite and cervical column deviations are described. It is suggested that this knowledge is incorporated in future diagnostic and orthodontic treatment planning.

**Key words:** cervical column morphology; skeletal open bite

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## Introduction

Many cephalometric studies have been performed on patients with skeletal open bite. Most of the authors agreed that the cephalometric characteristics found in patients with skeletal open bite were increased anterior facial height, increased gonial angle and mandibular plane angles, shorter anterior cranial base, upward and forward rotation of the maxilla and backward rotation of the mandible (1–8). Skeletal open bite develops as a result of many different aetiological factors including thumb and finger sucking, lip and tongue habits, airway obstruction and true skeletal growth abnormalities (e.g. 9–16).

So far, no study has included the cervical column morphology as a skeletal sign associated with skeletal open bite. Recently, an association between fusion of the bodies in the cervical column and deviations in the vertical and sagittal craniofacial morphology were found (17, 18). The location of fusion in the vertebral column was shown to be different in patients with condylar hypoplasia, patients with skeletal deep bite and skeletal mandibular overjet (17–19). Furthermore, the frequencies of malformations in the cervical column were different in the different malocclusion traits (17–19). Therefore, it is also relevant to look at the morphology of the cervical column in patients with skeletal open bite.

The aims of the present study were therefore: 1) to describe the morphology of the cervical column in adult patients with skeletal open bite; 2) to compare the morphology of the cervical column in a group of adult patients with skeletal open bite (open bite group) with the morphology of a control group with neutral occlusion and normal craniofacial morphology (control group); and 3) to analyse associations between the morphology of the cervical column and craniofacial dimensions in the total group (open bite and control group).

## Subjects

The *open bite group* consisted of 38 patients, 27 women, aged 17–39 years (mean 21.7), and 11 males, aged 18–40 years (mean 24.6). Inclusion criteria for the open bite group: 1) adult patients between 17 and 40 years of age; 2) no history of orthodontic treatment during childhood; 3) skeletal open bite [vertical jaw relationship larger than 1 SD according to the standard material described by Björk (20), assessed by lateral radiographs of each individual]; 4) at least 24 permanent teeth present; 5) no craniofacial anomalies or systemic muscle or joint disorders; 6) accessibility of a profile radiograph before pre-surgical orthodontic treatment with the first five cervical vertebrae units visible.

Thirty-eight profile radiographs were systematically selected according to the above-mentioned inclusion criteria from patients registered since 1975 in the orthodontic surgical patient archive (378 records) at the Department of Orthodontics, Copenhagen School of Dentistry, Denmark.

The *control group* consisted of 21 subjects, 15 females, aged 23–40 years (mean age 29.2), and six males aged 25–44 years (mean age 32.8). The subjects were either students or staff members at the Aarhus Dental School, Denmark. Selection criteria: 1) neutral occlusion or minor malocclusion not requiring orthodontic treatment according to the Danish procedure for screening the population for malocclusion entailing health risks (21, 22); 2) no previous history of orthodontic treatment; 3) sagittal and vertical jaw relationship within 1 SD according to the standard material described by Björk (20), assessed by lateral radiographs of each individual; 4) at least 24 permanent teeth present; 5) no craniofacial anomalies or systemic muscle or joint disorders; 6) availability of a profile radiograph with the five first cervical vertebrae units visible. The control group is previously described in detail by Sonnesen et al. (19).

## Methods

### Morphology of the cervical vertebrae

The visual assessment of the cervical column included the first five cervical vertebral units that are normally seen on a standardized lateral skull radiograph. Characteristics of the cervical column were classified according to Sandham (23) and divided into two categories: Posterior Arch Deficiency and Fusion Anomalies. Posterior Arch Deficiency consisted of partial cleft and dehiscence. Fusion Anomalies were registered in cases with fusion of two cervical bodies, block fusion when more than two bodies were fused and occipitalization of C1 and the occipital bone. Only anomalies that were verified on at least two profile radiographs before and after surgery from each individual were registered as anomalies of the cervical column.

### Craniofacial dimensions

For the control group the profile radiographs were taken with the teeth in occlusion and in the standardized head posture, the mirror position, as described by Siersbæk-Nielsen and Solow (24). The radiographs were taken at the Department of Oral Radiology,

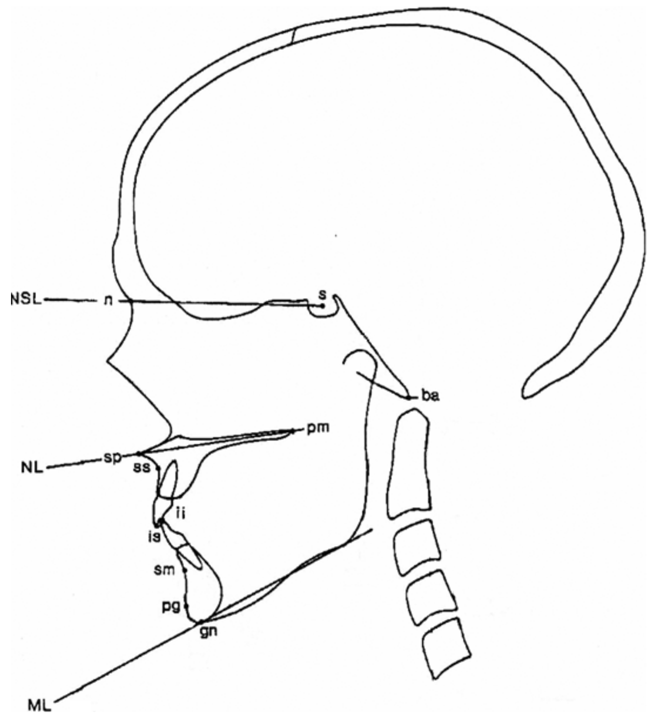


*Fig. 1.* Reference points and lines according to Solow and Tallgren, 1976 (35).

Aarhus Dental School, Denmark, in a Hofman Selectomat with a film-to-focus distance of 180 cm and a film-to-median plane distance of 10 cm. No correction was made for the constant linear enlargement of 5.6%. A plumb line was suspended from the ceiling to mark the true vertical line on the radiographs. The digital radiography system was a photostimulable phosphor plate, Digora (Soredex, Helsinki, Finland) placed in a traditional cassette without intensifying screen. The reference points were marked and digitized in PorDiosW (Fig. 1), and 10 variables representing the cranial base angle, the vertical and the sagittal craniofacial dimensions were calculated.

For the open bite group, the 38 profile radiographs were taken in a cephalostat with a film-to-focus distance of 180 cm and a film-to-median plane distance of 10 cm. No correction was made for the constant linear enlargement of 5.6% (1). A list of the variables is shown in Table 2.

#### Reliability

The reliability of the visual assessment of the morphological characteristics of the cervical vertebrae units was determined by inter-observer examinations between the authors. The inter-observer examinations showed 'very good' agreement ($K = 0.82$) as assessed by the kappa coefficient (25).

The reliability of the variables describing the cranial base, vertical and sagittal craniofacial dimensions was assessed by remeasurement of 20 lateral radiographs selected at random from the previously recorded radiographs. The radiographs were re-digitized, and the differences between the two sets of recordings were calculated. No significant differences between the two sets of recordings were found. The method errors ranged from 0.09 to 0.69° (26) and the reliability coefficients from 0.99 to 1.00 (27).

#### Statistical methods

The normality of the distributions was assessed by parameters of skewness and kurtosis and by Shapiro–Wilks *W*-test. The cephalometric measurements were normally distributed except for the overjet and overbite. Differences in means of the craniofacial dimensions between genders and between the groups were assessed by unpaired *t*-test. Differences in occurrence of morphological characteristics of the cervical column between genders and between the groups were assessed by Fisher's exact test. Associations between morphology of the cervical column and the craniofacial dimensions and the possible effect of age and gender were tested by logistic regression analyses. A multiple logistic regression analysis with stepwise backwards elimination was then performed to determine the relationship between the morphology of the cervical column as the dependent variable and the variables that were significantly correlated with the morphology of the cervical column as the independent variables. The correlation coefficients ($R^2$) in the logistic regression analyses were calculated according to Nagelkerke (28). In all the logistic regression models the linearity of the effect was tested by Hosmer–Lemeshow goodness-of-fit. The results from the tests were considered to be significant at $p$-values below 0.05. The statistical analyses were performed using SPSS 13.00 (SPSS Inc., Chicago, IL, USA).

## Results

#### Morphology of the cervical column

In the open bite group 42.1% had fusion of the cervical column, and 13.2% had posterior arch deficiency

(Table 1). The fusion always occurred between C2 and C3, and the posterior arch deficiency occurred in combination with fusion except for one patient (Fig. 2). No statistical gender differences were found in the occurrence of morphological characteristics of the cervical column (women 51.9%, men 18.2%).

As previously reported (19), in the control group 14.3% had fusion of the cervical column, and 4.8% had both fusion and posterior arch deficiency (Table 1). The fusion always occurred between C2 and C3. No statistical gender differences were found in the occurrence of morphological characteristics of the cervical column (women 13.3%, men 16.7%).

The *comparison* of the open bite group and the control group showed that fusions of the cervical column occurred significantly more often in the open bite group compared with the control group ($p < 0.05$, Table 1).

***Table 1.*** **Prevalence of morphological characteristics of the cervical column in patients with skeletal open bite (Open bite group) and in subjects with neutral occlusion and normal craniofacial morphology (Control group)**

| | Open bite group | | Control group | | |
|---|---|---|---|---|---|
| Variable | n | % | n | % | *p*-value |
| Normal | 21 | 55.3 | 18 | 85.7 | * |
| Fusion anomalies | 16 | 42.1 | 3 | 14.3 | * |
| Posterior arch deficiency | 5 | 13.2 | 1 | 4.8 | NS |
| More than one deviation | 4 | 10.5 | 1 | 4.8 | NS |

*$p < 0.05$, Fisher's exact test.
NS, not significant, Fisher's exact test.


*Fig. 2.* Morphological characteristics of the cervical column in patients with skeletal open bite. 1) Fusion of the cervical column vertebrae between C2 and C3 (fusion anomalies). 2) Partial cleft of the posterior portion of the neural arch of atlas (posterior arch deficiency).

#### Craniofacial dimensions

The mean values for the craniofacial dimensions are shown in Table 2. The sagittal jaw relationship (ss-n-sm, $p < 0.05$), the vertical jaw relationship (NL-ML, $p < 0.001$), the mandibular inclination (NSL-ML, $p < 0.001$) and the horizontal overjet ($p < 0.01$) were statistically larger in the open bite group than in the control group, whereas the maxillary (s-n-ss, $p < 0.05$) and mandibulary prognathia (s-n-pg,

***Table 2.*** **Craniofacial dimensions in the open bite group and in the control group**

| | Open bite (n = 38) | | Controls (n = 21) | | Group | Sex |
|---|---|---|---|---|---|---|
| Variable (degrees) | Mean | SD | Mean | SD | *p* | *p* |
| Sagittal dimensions | | | | | | |
| ss-n-pg | 3.30 | 3.89 | 1.58 | 1.92 | NS | NS |
| ss-n-sm | 4.11 | 3.49 | 2.14 | 1.59 | * | NS |
| s-n-ss | 78.81 | 4.20 | 81.64 | 2.97 | ** | NS |
| s-n-pg | 75.61 | 4.80 | 80.12 | 3.41 | *** | NS |
| Vertical dimensions | | | | | | |
| NL-ML | 36.45 | 4.23 | 22.32 | 3.13 | *** | NS |
| NSL-NL | 7.43 | 4.17 | 7.41 | 3.02 | NS | ‡ |
| NSL-ML | 43.88 | 5.15 | 29.71 | 4.81 | *** | NS |
| Cranial base angle | | | | | | |
| n-s-ba | 131.43 | 6.88 | 130.99 | 4.61 | NS | † |
| Incisor-relations | | | | | | |
| Overjet (mm) | 5.61 | 4.43 | 2.82 | 0.73 | ** | ‡ |
| Overbite (mm) | –3.24 | 2.98 | 2.30 | 0.96 | *** | NS |

***$p < 0.001$, unpaired t-test.
**$p < 0.01$, unpaired t-test.
*$p < 0.05$, unpaired t-test.
NS, not significant, unpaired *t*-test.
†$p < 0.01$, women larger than men, unpaired *t*-test.
‡$p < 0.05$, women larger than men, unpaired *t*-test.

$p < 0.001$) and the overbite ($p < 0.001$) were statistically smaller in the open bite group. The maxillary inclination (NSL-NL, $p < 0.05$), the cranial base angle (n-s-ba, $p < 0.01$) and the horizontal overjet ($p < 0.05$) were statistically significantly larger in women than in men.

#### Craniofacial dimensions related to the cervical column morphology

In the total group, the logistic regression analysis after correction of the possible effects of age and gender, showed that the maxillary retrognathia (s-n-ss, $p < 0.05$), a large maxillary inclination (NSL-NL, $p < 0.05$) and a large cranial base angle (n-s-ba, $p < 0.05$) were significantly correlated with fusion of the cervical column (Table 3).

The posterior arch deficiency was significantly correlated with the maxillary retrognathia (s-n-ss, $p < 0.05$) and a large cranial base angle (n-s-ba, $p < 0.05$) (Table 3). The significant regression coefficients (R) were low to moderate, numerical values ranging from 0.40 to 0.63 (Table 3).

The multiple logistic regression analysis showed that the most important factor for fusion of the cervical column and posterior arch deficiency was maxillary retrognathia (s-n-ss, $p < 0.01$, $R^2 = 0.20$; $p < 0.05$, $R^2 = 0.26$, respectively).

## Discussion

The aim of the present study was to examine the cervical column morphology in adult patients with skeletal open bite and compare the findings with the cervical column morphology in an adult control group with neutral occlusion and normal craniofacial morphology.

The cervical column morphology described in the skeletal open bite in the present study has not previously been reported in the literature. Similar studies have been performed on patients with skeletal deep bite, skeletal mandibular overjet and patients with condylar hypoplasia (17–19). In the present study the morphological deviations of the cervical column occurred in 42.1%, and the fusions of the cervical vertebral bodies always occurred between C2 and C3. A similar pattern is seen in the skeletal deep bite group where the morphological deviations of the cervical column occurred in 41.5%, also between C2 and C3 (17). Compared to these findings in the skeletal open bite and skeletal deep bite, the prevalence was even larger in a group of patients with skeletal mandibular overjet (61.4%) (18) and in a group of patients with condylar hypoplasia (72.7%) (19). Furthermore, the pattern of the cervical column morphology was different in skeletal open bite and skeletal deep bite compared to the group of patients with mandibular overjet and condylar hypoplasia. In the condylar hypoplasia group fusions occurred not only between C2 and C3 but also between C3 and C4, and in the mandibular overjet group fusions characterized as block fusion also occurred. It can be concluded from this comparison that the cervical column morphology differs phenotypically in the different skeletal malocclusion traits.

In the present study an association was found between cervical column morphology, maxillary retrognathia and increased maxillary inclination. With regard to the cephalometric registration of maxillary deviations it is interesting to compare the present findings with findings in cleft palate patients. Previously, an association has been shown between isolated cleft palate patients and maxillary retrognathia and increased maxillary inclination (29, 30).

Furthermore, an association has been found between isolated cleft palate patients and malformations of the upper cervical vertebrae (23, 31, 32). This comparison may indicate that the aetiology behind the skeletal open bite is an abnormal development in the maxilla during the early prenatal period. As the maxilla develops from neural crest cell migration (33), it is understandable that the disturbance in the amount of migrating maxillary cells or the timing of the migration of the maxillary cells may influence the

***Table 3.*** **Significant correlations (*R*) after correction of age and gender effect between morphology of the cervical column and the maxillary retrognathia (s-n-ss), inclination of the maxilla (NSL-NL), and cranial base angle (n-s-ba) in the total group (n = 59)**

| | Fusion | Posterior arch deficiency | More than one deviation |
|---|---|---|---|
| s-n-ss | −0.59‡ | −0.51* | −0.49* |
| NSL-NL | 0.60‡ | NS | NS |
| n-s-ba | 0.62‡ | 0.48* | 0.40* |

*$p < 0.05$ (logistic regression).
‡$p < 0.05$ and negative effect of age (logistic regression).
NS, not significant (logistic regression).

sagittal development (maxillary retrognathia), the vertical development (maxillary inclination) and the transversal development (palatal closure). This hypothesis may be included in future studies of the aetiology of skeletal malocclusion traits.

In the present study an association was found between cervical column morphology and a large cranial base angle. This finding was in agreement with recent studies on cervical vertebrae malformation and craniofacial morphology (17, 19). From an embryological point of view this interrelation is understandable as both the vertebral corporae and the basilar part of the occipital bone has developed in close association with the notochord and in direct induction from the notochord (34). The precise signalling from the notochord in the body axis to the neural crest followed by bilateral cell migration to the craniofacial area is still not known.

The findings in the present study revealed the importance of including not only the genetic background but also the early embryological developmental pattern in the understanding of the aetiology behind skeletal malocclusion traits.

In the present study new associations between skeletal open bite and cervical column deviations are described. It is suggested that this knowledge is incorporated in future diagnostics and orthodontics treatment planning.

## Conclusions

New associations between skeletal open bite and cervical column deviations are described. It is suggested that this knowledge is incorporated in future diagnostic and orthodontic treatment planning.

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