The relationship between maxillary dental and occlusal anomalies: evidence of a ‘Maxillary Deficiency Syndrome’

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Introduction: Recent reports have suggested that anomalies involving the maxillary dentition can sometimes occur in combination. The aim of the study was to investigate combinations of maxillary dental anomalies relating to occlusal and skeletal factors which could suggest a ‘syndrome-like’ aetiology.

Method: This report is based on observations of study models and cephalograms of individuals exhibiting dental anomalies or malocclusion traits related to maxillary or maxillary arch development. A series of nine dental and skeletal anomalies was defined. A possible inter-relationship between the dental factors as well as a correlation with the skeletal malocclusion traits and skeletal factors was investigated.

Results: Of the 253 cases examined, 157 demonstrated single dental symptoms; the remainder demonstrated a combination of at least two or more. Dental and occlusal anomalies in maxillary development were usually associated with bi-maxillary jaw retrognathism and a low mandibular ramus height, indicating a vertical mandibular developmental pattern.

Conclusions: Maxillary anomalies based on the finding of aplasia, eruption problems or crossbite could occur in combination and be associated with constricted skeletal development of the palate or atypical mandibular morphology. It is proposed that these findings suggest the existence of a Maxillary Deficiency Syndrome which should be considered carefully when orthodontic treatment planning.

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Introduction
The formation, growth and development of the maxilla represents a complicated embryological and post-natal process within the dento-facial complex. Disturbances in this process lead to malformation of the anterior palate and lip, as evidenced by the formation of cleft lip and palate, as well as more minor developmental anomalies that can manifest as problems involving the formation, position and/or eruption of single or multiple teeth. Other clinical anomalies related to maxillary development include discrepancies in tooth position and occlusion which, superficially at least, appear to be localised to the maxilla and the maxillary dental arch. A number of studies, typified by Ellis and McNamara, have demonstrated how the anomalous development of the skeletal maxilla can be related to sagittal discrepancies in the form of a Class III malocclusion, as well as vertical discrepancies of which open bite is representative. This connection between skeletal sagittal and vertical discrepancies was further illustrated by a description of facial form in association with cleft palate disorders. The facial form related to clefts involving the primary and secondary palates could also be noted in cases of minor severity involving isolated cleft palate. The associated skeletal morphology included a combination of a flattened cranial base, a short anterior cranial fossa, a short retrognathic maxilla and a generally low facial height in the midface region. An analysis of mandibular
morphology determined a flat mandibular base and a short ramus. Additional studies describing facial form in patients with minor discrepancies in maxillary development have also reported a facial pattern that resembles that seen in connection with cleft palate syndrome.  

In a consideration of the aetiological factors that could lead to malformation of the palate, the role of genetics has been highlighted. Thesleff  and van der Boogaard  suggested that anomalies in dental formation as well as craniofacial development were both mediated by the MSX1 gene. A later study demonstrated the role of the LTBP3 gene in the formation of the teeth, supporting the involvement of genetic factors in connection with the aetiology of maxillary developmental anomalies. Underlining the important role played by the maxilla in facial development, a study describing the facial morphology of young individuals who would develop a true Class III malocclusion stressed the role of maxillary dysplasia (retrognathia) in situations previously described as the result of mandibular overdevelopment (prognathia).

At the dental level, hypodontia is a common form of maxillary discrepancy, affecting particularly the lateral incisors in 5.5% of Europeans, with a slight predominance in females. In a retrospective study of 3872 orthodontic patients, Celikoglu et al. reported 2.4% of cases exhibited missing lateral incisors (more frequent in females) and, interestingly, 20.2% peg-shaped lateral incisors. In addition, the ectopic eruption of maxillary canines was relatively frequent and observed in 21.3% of the cases examined. Many studies have investigated the relationship between non-syndromic hypodontia and craniofacial form, and frequently demonstrated a reduction in maxillary prognathism, although this finding has been disputed. In some cases, it has been suggested that missing maxillary lateral incisors could be related to a significant reduction in the sagittal jaw relationship, leading to a Class III type of malocclusion. In the vertical plane, the consensus seems to be that anterior facial height was reduced in many cases of hypodontia. In a study of 277 subjects, Acharya et al. demonstrated that patients with varying degrees of hypodontia exhibit variations in facial morphology, frequently with a tendency towards a Class III occlusal relationship with the effect greatest in the maxilla. The severity of the observed morphological discrepancies was related to the number and location of the missing teeth. These findings contradict those of Lisson and Scholtes, who suggested that variations in facial morphology seen in connection with hypodontia did not relate to the number of missing teeth.

In a similar cephalometric study of children with at least two teeth missing in one jaw, Kreczi et al. observed that individuals with hypodontia exhibited a tendency to bi-maxillary retrognathism and a decrease in the vertical plane, expressed by the so-called Hasund ratio. At the same time, in a consideration of the growth pattern, it was suggested that no dominant type of mandibular rotation could be observed. The observation of a reduction of lower anterior facial height was supported by an investigation of 42 patients and a number of other cephalometric studies, which could not be corroborated and were contradicted by Chung et al., who reported an increase in the maxillo-mandibular angle.

Créton et al. studied the lateral cephalograms of 189 individuals with various degrees of hypodontia, oligodontia and tooth agenesis and revealed that facial morphology differed from a general orthodontic population in both dental and skeletal aspects. Using a cluster analysis, four different groups were described, one a high angle facial pattern, two groups based on the inclination of the mandibular incisors which were proclined or retroclined respectively and a fourth group that comprised individuals with a retrognathic maxillary position. A group of subjects with the largest number of missing teeth was characterised by a maxillary retrognathism and low anterior facial height.

A study by Woodworth et al. described the dento-facial morphology of patients with aplasia as characterised by a smaller maxillary length, a shorter anterior cranial base, reduced vertical dimensions anteriorly and posteriorly, as well as a reduced mandibular plane angle. Using a linear analysis, the maxilla was found to be retrusive, which suggested a correlation with a shortening of the anterior cranial base. It was noted that the SNA angle was not reduced as expected in connection with maxillary retrusion, likely due to the geometrical influence of the shortened anterior cranial base on the position of the point, nasion. Celigocklu et al. have also reported other abnormal characteristics in tooth and arch formation in association with aplasia of incisors, including ectopic maxillary canines, peg-shaped lateral incisors, dilacerations or transposition; and, further, indicated that 62% of patients with...
agenesis of maxillary incisors exhibited one or more of the named symptoms. In an article considering the growth pattern of patients with missing teeth, Bauer et al. 25 evaluated the mandibular growth pattern (mandibular morphology) *ad modum* Hasund, and found no difference in the morphology of individuals exhibiting aplasia and a control group. These findings were supported by Kreczi et al. 19.

The ectopic formation of maxillary canines is also a relatively frequently occurring phenomenon, being observed in 21.3% of orthodontic cases and 5% in the total population. 10 Focusing on dental/skeletal features associated with unilateral or bilateral palatal displacement of maxillary canines, Sacerdoti and Baccetti 26 found that unilateral discrepancies were associated with aplasia of the lateral incisors, whereas bilateral palatal displacement seemed also to be associated with aplasia of third molars. Considering the dental and skeletal characteristics of patients with displacement of the permanent maxillary canines in a study of 144 patients, Cernochova and Izakovicova-Holla 11 described a more frequent occurrence of retrognathic maxilla and a skeletal Class III pattern in patients with buccally-displaced canines. The same study reported a prognathic maxilla and a Class I relationship in patients with palatally-displaced canines, suggesting a relationship between dento-facial characteristics and maxillary canine eruption.

The relationship between missing maxillary incisors and other forms of maxillary malformation or dysplasia, such as ectopic canine eruption, transposition and peg-shaped lateral incisors, has been noted. 8 A study by Gungor and Turkkahraman 9 on the effect of non-syndromic hypodontia on craniofacial morphology concluded that the severity and location of the missing teeth has a significant effect on craniofacial morphology.

The aims of the present study were:

(1) To investigate the frequency and inter-relationship of a series of dental and malocclusion traits related to the maxilla, both alone and in combination.

(2) To investigate the dento-facial form in patients exhibiting dental and occlusal anomalies involving the maxilla.

The study was based on the identification of one or more of the following forms of dental or occlusal discrepancies that hypothetically, directly or indirectly, were considered to involve the formation and development of the maxilla.

(1) Aplasia of one or more maxillary lateral incisors.

(2) Conical morphology (peg shape) of one or more maxillary lateral incisors.

(3) Anterior crossbite, defined as a reverse overjet on one, two or three maxillary incisors.

(4) Negative overjet, defined as a reverse overjet on all four maxillary incisors.

(5) Lateral crossbite, defined as palatal occlusion on the buccal cusp of either maxillary premolars and/or the first permanent maxillary molar or a maxillary canine.

(6) Anterior open bite, defined as a negative vertical overlap on at least three maxillary incisors.

(7) Lateral open bite, defined as lack of occlusal contact on all premolars and first permanent molars on at least one side.

(8) Reduced vertical overlap in the incisor region, defined as an overbite of a maximum of 1.0 mm on at least one maxillary incisor.

(9) Mal-eruption of maxillary canines (ectopia) either buccally or palatally on at least one maxillary incisor.

**Material and methods**

The material for the present study was based on retrospective data from records (study casts and lateral cephalograms) of 253 individuals (66 males and 187 female), with an average age of 23 years 6 months, and ranging from nine years three months to 47 years 10 months, selected from the private orthodontic practice of one of the authors (SW). Each individual was registered in connection with the commencement of orthodontic therapy and each chosen for inclusion in the study by the one author (BWL) based on the observation of one or more of the above occlusal or dental symptoms (1–9).

The control group data consisted of 122 volunteers (average age 18.0 years) selected on the basis of an acceptable occlusion and without any of the investigated maxillary malocclusion traits. A detailed description of this material has been published previously 27 and the study has received bioethical consent (certificate approval number KBET/89/B/2009).
The frequency of symptoms thought to indicate maxillary deficiency and their inter-relationship is shown in Table I.

The facial morphology component of the study was based on a cephalometric evaluation of the experimental group taken under standardised conditions. All radiographs were traced and measured by one investigator (BWL) using a standard digital measuring system subsequent to digitisation of the analogue radiographs. Measurements were carried out using parameters defined in the ‘Kracovia composite cephalometric analysis’ reported elsewhere. For the purposes of the present study the cephalometric analysis was reduced in order to focus on factors related to the position and size of the maxilla as well as a parameter, the ‘Beta angle’, which describes mandibular morphology and is thought to relate to the mandibular growth pattern.

The morphological study was performed in two stages, the first of which involved a comparison between values recorded for the test patients (N = 253) compared with the control material (N = 122), reported in Table II. The second stage comprised a comparison between subgroups selected on the basis of magnitude of the observed differences in the first stage.

### Table I. Observed frequency (n) and inter relationship between symptoms of maxillary deficiency in the total material (N = 253).

| Symptom                        | n   | %   |
|--------------------------------|-----|-----|
| Total sample N = 253           |     |     |
| Aplasia 12/22 (Ap)             | 14  | 5.53|
| Conical teeth 12/22 (Ct)       | 14  | 5.53|
| Anterior crossbite (Ac)        | 26  | 10.27|
| Negative overjet (No)          | 21  | 8.30 |
| Lateral crossbite (Lc)         | 99  | 39.13|
| Anterior open bite (Aob)       | 34  | 13.44|
| Lateral open bite (Lob)        | 16  | 6.32 |
| Reduced overbite (Ro)          | 28  | 11.06|
| Mal eruption canines (Mc)      | 113 | 44.66|

### Table II. Cephalometric comparison between the total study group (N = 253) and a control group (N = 122).

| Control / Max def (total sample) N = 253 | Control / Max def (total sample) N = 122 |
|-----------------------------------------|-----------------------------------------|
| Sagittal jaw relationship               |                                          |
| 1 A-N-Pg                                | 1.24 N=122                               |
| 2 A-N-B                                 | 2.54 N=253                               |
| 3 WITs                                  | 1.05 N=122                               |
| Jaw prognathism                         |                                          |
| 4 Maxillary (S-N-A)                     | 82.22 N=122                              |
| 5 Mandibular (S-N-Pg)                   | 81.00 N=253                              |
| 6 Mandibular (S-N-B)                    | 79.69 N=122                              |
| Vertical relationship                   |                                          |
| 7 Vertical jaw relationship (NL/ML)     | 20.76 N=122                              |
| 8 Maxillary inclination (SN/NL)         | 8.34 N=253                               |
| 9 Mandibular inclination (SN/ML)        | 29.09 N=122                              |
| Mandibular morphology                   |                                          |
| 10 Beta angle                           | 22.20 N=122                              |
| Cranial base                            | 130.85 N=253                             |
| Jaw length                              |                                          |
| 12 Maxillary length                     | 54.43 N=122                              |

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of the observation of one specific maxillary symptom, ‘lead factor’, each compared individually with the control group, the results shown in Table IIIα-i.

Statistical comparisons against the control material, were made by means of a ‘student t-test’, following confirmation of suitable distribution and homogeneity of variance.

**Results**

The relative frequency of, and interrelation between, the various anomalies involving the maxilla may be seen in Table I. An overview of the figures revealed that, of the 253 cases examined, 157 subjects (62%) demonstrated only one of the named symptoms; the other 96 showed various combinations of symptoms that are similarly documented in Table I.

Mal-eruption of one or both maxillary canines and a lateral crossbite were the most commonly observed symptoms, affecting 113 individuals (44%) and 99 individuals (39%) in each group respectively. Anomalies involving the sagittal incisal relationship were also clearly represented in the data with 10.3% of subjects demonstrating anterior crossbite and a further 8.3% a negative overjet. Vertical problems were represented by an anterior open bite observed in 13.4% and lateral open bite in 6.3% of cases, whereas a reduced incisal overbite was observed in 28 cases (11.06%). Aplasia of the lateral maxillary incisor(s) was less frequent at 5.5%, with a similar frequency (5.3%) of patients exhibiting one or more conical (peg-shaped) lateral incisors.

The inter-relationship between the various dental and occlusal symptoms is also reported in Table I, which records that a lateral crossbite was most frequently related to other symptoms, particularly anterior crossbite, negative overjet, anterior open bite and a reduced incisal overbite. In a like manner, ectopic canine eruption was frequently related to other symptoms of the maxillary dentition or occlusion; in particular a lateral crossbite and also, to a lesser degree, to each of the other identified symptoms with the exception of aplasia of at least one maxillary incisor.

Table II compares the morphology of the entire patient group (N = 253) demonstrating one or more of the maxillary developmental anomalies as well as the occlusion, with the control group. The results showed a clear difference in morphology between the two groups. While the sagittal jaw relationship expressed as an angular parameter (var. 1, 2) was not

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**Table IIIα.** Comparison between groups of the experimental material and the control material in terms of missing maxillary incisors.

|                                    | Control | s.d. | Aplasia | s.d. | t     | Sig. |
|------------------------------------|---------|------|---------|------|-------|------|
| **Sagittal jaw relationship**      |         |      |         |      |       |      |
| 1 AN-Pg                            | N=122   | 1.31 | 2.86    | 1.10 | 2.90  | 0.246| ns   |
| 2 AN-B                             | 2.56    | 2.44 | 2.56    | 2.07 | 0.009 | ns   |
| 3 WITS                             | 1.05    | 2.63 | 0.3     | 2.7  | 0.967 | ns   |
| **Jaw prognathism**                |         |      |         |      |       |      |
| 4 Maxillary (A)                    | 81.72   | 3.69 | 79.54   | 3.11 | 2.354 | *    |
| 5 Mandibular (Pg)                  | 80.42   | 4.00 | 78.45   | 3.48 | 1.909 | ns   |
| 6 Mandibular (B)                   | 79.16   | 3.80 | 76.99   | 3.29 | 2.231 | *    |
| **Vertical relationship**          |         |      |         |      |       |      |
| 7 Vertical jaw relationship        | 21.18   | 5.81 | 25.61   | 7.74 | 2.009 | *    |
| 8 Maxillary inclination            | 8.88    | 2.92 | 6.66    | 4.32 | 1.803 | ns   |
| 9 Mandibular inclination           | 30.05   | 6.08 | 32.29   | 7.74 | 1.014 | ns   |
| **Mandibular morphology**         |         |      |         |      |       |      |
| 10 Beta angle                      | 22.13   | 2.94 | 21.42   | 3.29 | 0.748 | ns   |
| 11 Cranial base                    |         |      |         |      |       |      |
| 12 NS-ba                           | 130.85  | 5.23 | 130.56  | 5.46 | 0.188 | ns   |
| **Jaw length**                     |         |      |         |      |       |      |
| 13 Maxillary length                | 53.68   | 3.04 | 49.73   | 2.47 | 5.353 | ***  |
Table IIIb. Comparison between groups of the experimental material and the control material in terms of conical anomaly of maxillary incisors.

| Control / Max def (conical) | Control | s.d. | Conical teeth | s.d. | t     | Sig. |
|-----------------------------|---------|------|---------------|------|-------|------|
| Sagittal jaw relationship   | N=122   | N=14 |               |      |       |      |
| 1 AN-Pg                     | 1.31    | 2.86 | 1.78          | 2.67 | 0.601 | ns   |
| 2 AN-B                      | 2.56    | 2.44 | 2.96          | 2.55 | 0.537 | ns   |
| 3 WITS                      | 1.05    | 2.63 | 0.4           | 3.19 | 0.734 |      |

Jaw prognathism

| Jaw prognathism             | Control | s.d. | Conical teeth | s.d. | t     | Sig. |
|-----------------------------|---------|------|---------------|------|-------|------|
| Maxillary (A)               | 81.72   | 3.69 | 79.38         | 5.31 | 1.549 | ns   |
| Mandibular (Pg)             | 80.42   | 4.00 | 77.61         | 5.11 | 1.914 | ns   |
| Mandibular (B)              | 79.16   | 3.80 | 76.42         | 5.55 | 1.735 | ns   |

Vertical relationship

| Vertical relationship      | Control | s.d. | Conical teeth | s.d. | t     | Sig. |
|----------------------------|---------|------|---------------|------|-------|------|
| Vertical jaw relationship  | 21.18   | 5.81 | 30.79         | 6.04 | 5.469 | *** |
| Maxillary inclination      | 8.88    | 2.92 | 6.08          | 4.66 | 2.122 | *    |
| Mandibular inclination     | 30.05   | 6.08 | 36.88         | 7.98 | 2.994 | **   |

Mandibular morphology

| Beta angle                 | 22.13   | 2.94 | 19.47         | 2.33 | 3.809 | *** |

Cranial base

| N-S-ba                     | 130.85  | 5.23 | 131.14        | 5.16 | 0.186 | ns   |

Jaw length

| Maxillary length           | 53.68   | 3.04 | 50.89         | 2.87 | 3.308 | *** |

Table IIIc. Comparison between groups of the experimental material and the control material in terms of the facial morphology of patients exhibiting an anterior cross bite.

| Control / Anterior crossbite | Control | s.d. | Anterior crossbite | s.d. | t     | Sig. |
|------------------------------|---------|------|--------------------|------|-------|------|
| Sagittal jaw relationship    | N=122   | N=26 |                   |      |       |      |
| 1 AN-Pg                      | 1.31    | 2.86 | 1.38               | 2.74 | 0.127 | ns   |
| 2 AN-B                       | 2.56    | 2.44 | 2.17               | 2.40 | 0.737 | ns   |
| 3 WITS                       | 1.05    | 2.63 | -1.1               | 2.80 | 3.592 | *** |

Jaw prognathism

| Jaw prognathism             | Control | s.d. | Anterior crossbite | s.d. | t     | Sig. |
|----------------------------|---------|------|--------------------|------|-------|------|
| Maxillary (A)               | 81.72   | 3.69 | 80.57              | 3.69 | 1.417 | ns   |
| Mandibular (Pg)             | 80.42   | 4.00 | 79.18              | 3.45 | 1.585 | ns   |
| Mandibular (B)              | 79.16   | 3.80 | 78.41              | 3.15 | 1.047 | ns   |

Vertical relationship

| Vertical relationship      | Control | s.d. | Anterior crossbite | s.d. | t     | Sig. |
|----------------------------|---------|------|--------------------|------|-------|------|
| Vertical jaw relationship  | 21.18   | 5.81 | 27.27              | 6.56 | 4.312 | *** |
| Maxillary inclination      | 8.88    | 2.92 | 7.20               | 3.22 | 2.415 | *    |
| Mandibular inclination     | 30.05   | 6.08 | 34.49              | 6.34 | 3.218 | *** |

Mandibular morphology

| Beta angle                 | 22.13   | 2.94 | 19.73              | 3.51 | 3.199 | **   |

Cranial base

| N-S-ba                     | 130.85  | 5.23 | 131.34             | 4.43 | 0.482 | ns   |

Jaw length

| Maxillary length           | 53.68   | 3.04 | 49.63              | 2.81 | 6.465 | *** |
reduced, when the linear ‘Wits’ analysis was applied (var. 3) a slight negative value (-1.0 *) was observed. The general level of jaw prognathism was reduced (var. 3, 4, 5 all ***), the length of the maxilla (var. 12) was significantly reduced in the experimental group (t = 0.3430 ***). In the vertical plane, the jaw relationship was increased in the experimental group (var. 6 ***) as a result of a posterior inclination of the mandible (var. 8 ***). The ‘Beta’ angle describing mandibular morphology was clearly reduced (var. 10 ***), indicating a low ramus height relative to the mandibular corpus.

The results of the statistical analysis comparing one particular factor against the control material 27 can be seen in Tables IIIa-i.

Table IIIa pertains to missing maxillary incisors and describes a general tendency to maxillary retrognathism in these subjects. While sagittal jaw relationships (variables 1, 2 and 3) are similar between the two groups, maxillary prognathism at A point was reduced (var. 4, 79.54**), as was mandibular prognathism, but only when measured at B point (var. 6, 76.99**). The vertical jaw relationship was increased (var. 7, 25.61 *) as a result of a slight, insignificant anterior inclination of the maxilla (var. 8) and a posterior inclination of the mandible (var. 9). A significant decrease was seen in the length of the maxilla (var. 27, 49.73 mm ***).

Table IIIb analyses facial form in subjects exhibiting a conical anomaly of at least one maxillary incisor (peg-shaped lateral). A similarity in the variables illustrating jaw prognathism is demonstrated through an enlarged vertical jaw relationship (var. 7, 30.79***), as a result of a slight anterior inclination of the maxilla (var. 11, 30.79***) and a clear increase in the inclination of the mandible (var. 9, 36.88° **). The mandibular morphology was characterised by a reduced ramus height, resulting in a reduced \( \beta \) angle (var. 10, 19.47°***) and a considerably reduced maxillary length (var. 27, 50.89 mm ***).

The facial morphology of patients exhibiting an anterior cross bite (Table IIIc) was characterised by a normal sagittal relationship (var. 1, 2) though a negative sagittal jaw relationship (var. 3, -1.1 mm***) when the Wits analysis was considered. An increase in a vertical jaw relationship (var. 7, 27.27° ***) and an anterior inclination of the maxilla (var. 8, 7.20° ***) combined with the significant increase in the inclination of the mandible (var. 9, 34.49****), accompanied by a significant decrease in the \( \beta \) angle (var. 10, 19.73***), indicated a difference in mandibular morphology.
Table IIIe. Comparison between groups of the experimental material and the control material in terms of a lateral cross bite.

|                                | Control / Max def (lat crossbite) | Control     | s.d.     | Lat crossbite | s.d.     | t       | Sig. |
|--------------------------------|----------------------------------|-------------|----------|---------------|----------|---------|------|
| **Sagittal jaw relationship**  | N=122                            | N=21        |          |               |          |         |      |
| 1 A-N-Pg                       | 1.31                             | 2.86        | 0.74     | 3.52          | 1.284    | ns      |      |
| 2 A-N-B                        | 2.56                             | 2.44        | 1.65     | 3.29          | 2.265    | *       |      |
| 3 WITS                         | 1.05                             | 2.63        | -1.5     | 4.714         | 3.136    | ***     |      |
| **Mandibular morphology**      |                                  |             |          |               |          |         |      |
| 4 Maxillary (A)                | 81.72                            | 3.69        | 80.03    | 3.86          | 3.293    | ***     |      |
| 5 Mandibular (Pg)              | 80.42                            | 4.00        | 79.29    | 4.69          | 1.894    | *       |      |
| 6 Mandibular (B)               | 79.16                            | 3.80        | 78.37    | 4.69          | 1.353    |         |      |
| **Cranial base**               |                                  |             |          |               |          |         |      |
| 11 N-S-ba                      | 130.85                           | 5.23        | 130.21   | 4.36          | 1.005    | ns      |      |
| **Jaw length**                 |                                  |             |          |               |          |         |      |
| 12 Maxillary length            | 53.68                            | 3.04        | 49.66    | 3.93          | 8.316    | ***     |      |

Table IIIe describes patients exhibiting a reverse overjet of all four incisors, in which the sagittal jaw relationship was significantly reduced (to a negative value) (var. 1, -1.66°), though less when expressed at B point (var. 2, -1.43° ns). While maxillary prognathism (var. 5) between the two groups revealed no difference, mandibular prognathism was significantly higher in the negative overjet group (var. 5, 83.40° and var. 6, 83.17°). The vertical jaw relationship was significantly increased in the negative overjet group (var. 11, 25.26°). Mandibular morphology in the negative overjet group was characterised by the reduced β angle (var. 10, 18.98°) and maxillary length was also significantly reduced in this group (var. 12, 48.67 mm).

Patients exhibiting a lateral cross bite (Table IIIe) exhibited facial morphology of a reduced sagittal jaw relationship (var. 2, 1.65°) and Wits evaluation (var. 3, -1.5 mm), as well as maxillary prognathism (var. 4, 80.03°), and a slight, non-significant reduction in mandibular prognathism (var. 6). In the vertical plane, the jaw relationship (var. 7, 27.57°) and the mandibular inclination (var. 9 34.36°) were significantly increased, which was accompanied by a reduction in the β angle describing mandibular morphology (var. 10, 19.92°). No significant difference in cranial base flexure (var. 11) was seen, though the maxillary length was significantly reduced (var. 12, 49.66 mm).

Patients exhibiting an anterior open bite (Table IIIf) displayed facial morphology characterised by an increased sagittal jaw relationship (var. 1, 2.99°) with bi-maxillary retrognathism (var. 3, 4, 5) and an increased vertical jaw relationship (var. 7, 32.92°), as a combination of decreased maxillary inclination (var. 8, 5.62°) and an increased mandibular inclination (var. 9, 38.54°). Again, the β angle was significantly decreased (var. 10, 18.70°), matching a reduction in the length of the maxilla (var. 12, 50.51 mm).

In a consideration of patients with a lateral open bite (Table IIIg), the sagittal jaw relationship was similar when comparing the two groups (var. 1 and 2), although the Wits analysis demonstrated a negative sagittal relationship (var. 3, -2.80 mm). The experimental group exhibited a bi-maxillary retrognathism (var. 3, 4 and 5) with an increased vertical jaw relationship (var. 7, 29.4°) and mandibular inclination (var. 9, 37.79°). The β angle was reduced in the open bite group (var. 10, 19.60°) and maxillary length was reduced (var. 12, 49.79 mm).
### Table IIIf. Comparison between groups of the experimental material and the control material in terms of an anterior open bite.

| Control/Max def (ant open bite) | Control  | s.d.   | Ant open | s.d.   | t      | Sig. |
|--------------------------------|----------|--------|----------|--------|--------|------|
| Sagittal jaw relationship      | N=122    | N=34   |          |        |        |      |
| 1 A-N-Pg                       | 1.31     | 2.86   | 2.99     | 3.41   | 2.639  | **   |
| 2 A-N-B                        | 2.56     | 2.44   | 3.55     | 3.46   | 1.562  | ns   |
| 3 WITS                         | 1.05     | 2.63   | 0.8      | 5.58   | 0.263  | ns   |

**Jaw prognathism**

| 4 Maxillary (A)                | 81.72    | 3.69   | 80.04    | 3.05   | 2.704  | **   |
| 5 Mandibular (Pg)              | 80.42    | 4.00   | 77.05    | 4.03   | 4.322  | ***  |
| 6 Mandibular (B)               | 79.16    | 3.80   | 76.49    | 4.10   | 3.411  | ***  |

**Vertical relationship**

| 7 Vertical jaw relationship    | 21.18    | 5.81   | 32.92    | 6.08   | 10.057 | ***  |
| 8 Maxillary inclination        | 8.88     | 2.92   | 5.63     | 3.05   | 5.548  | ***  |
| 9 Mandibular inclination       | 30.05    | 6.08   | 38.54    | 5.07   | 8.252  | ***  |

**Mandibular morphology**

| 10 Beta angle                  | 22.13    | 2.94   | 18.70    | 2.36   | 7.091  | ***  |

**Cranial base**

| 11 N-S-ba                      | 130.85   | 5.23   | 130.18   | 4.93   | 0.699  | ns   |

**Jaw length**

| 12 Maxillary length            | 53.68    | 3.04   | 50.51    | 4.19   | 4.120  | ***  |

### Table IIIg. Comparison between groups of the experimental material and the control material in terms of a lateral open bite.

| Control / Max def (lat open bite) | Control  | s.d.   | Lat open | s.d.   | t      | Sig. |
|-----------------------------------|----------|--------|----------|--------|--------|------|
| Sagittal jaw relationship         | N=122    | N=16   |          |        |        |      |
| 1 A-N-Pg                          | 1.31     | 2.86   | 2.99     | 3.41   | 0.241  | ns   |
| 2 A-N-B                           | 2.56     | 2.44   | 3.55     | 3.46   | 1.562  | ns   |
| 3 WITS                            | 1.05     | 2.63   | 0.8      | 5.58   | 0.263  | ns   |

**Jaw prognathism**

| 4 Maxillary (A)                  | 81.72    | 3.69   | 80.04    | 3.05   | 2.704  | **   |
| 5 Mandibular (Pg)                | 80.42    | 4.00   | 77.05    | 4.03   | 4.322  | ***  |
| 6 Mandibular (B)                 | 79.16    | 3.80   | 76.49    | 4.10   | 3.411  | ***  |

**Vertical relationship**

| 7 Vertical jaw relationship      | 21.18    | 5.81   | 29.04    | 6.09   | 4.745  | ***  |
| 8 Maxillary inclination          | 8.88     | 2.92   | 8.74     | 3.23   | 0.152  | ns   |
| 9 Mandibular inclination         | 30.05    | 6.08   | 37.79    | 5.06   | 5.462  | ***  |

**Mandibular morphology**

| 10 Beta angle                    | 22.13    | 2.94   | 19.60    | 2.25   | 3.968  | ***  |

**Cranial base**

| 11 N-S-ba                        | 130.85   | 5.23   | 132.31   | 5.96   | 0.906  | ns   |

**Jaw length**

| 12 Maxillary length              | 53.68    | 3.04   | 48.79    | 3.22   | 5.587  | ***  |
Subjects exhibiting a reduced vertical overbite in the incisor region (max 1.0 mm), although without an open bite (Table IIIh), showed facial form dominated by a tendency towards bi-maxillary retrognathism, (var. 3, 78.68°*** and var. 4, 77.99°**) but with a normal sagittal jaw relationship. The vertical jaw relationship (var. 7) was increased (28.99°*** as a reduction in maxillary inclination (var. 8, 7.70°) and an increased mandibular inclination (var. 9, 36.67°****). The β angle describing mandibular morphology (var. 10, 19.65°*** was reduced, as was maxillary length (var. 27, 48.84 mm ***).

The facial form of patients exhibiting problems with maxillary canine eruption (palatal or buccal ectopia) (Table IIIi) was dominated by bi-maxillary retrognathism, as shown by variables 3 (79.94°***), 4 (77.98°****) and 5 (77.04°**) and an increased vertical jaw relationship (var. 11, 27.15°***) and variable 13 (34.74°***) with a decreased maxillary inclination (var. 12, 7.59°***). The β angle (var. 16), describing mandibular morphology, was similarly reduced (20.10 ***).

Discussion
Dental problems and/or malocclusions involving the maxilla constitute a considerable orthodontic workload, and it is expected that a greater understanding of the aetiology and morphological characteristics would improve therapeutic techniques. The aim of the present report was to present and discuss a number of factors related to these maxillary anomalies.

The material on which the present study was based comprised 253 individuals who were selected a priori for orthodontic treatment, who exhibited at least one of the outlined symptoms and were considered to represent a problem involving the development of the maxilla or the maxillary dentition. The results of the cephalometric analysis of patients exhibiting anomalies of formation and/or eruption of maxillary teeth or malocclusion related to the maxilla demonstrated a clear and typical pattern. In a comparison of the entire experimental group against the control group, a normal sagittal jaw relationship was apparent when evaluated by the A-N-Pg or A-N-B angles. This supported the findings of several other studies; 3, 13-17, 21-24, 30, 31 although when the Wits analysis was applied, a clear average negative sagittal relationship was recorded, which illustrated a lack of correlation between the angular and linear expression of the sagittal jaw relationship. 32 The increase in vertical jaw relationship observed in the experimental group contradicts the observation of a reduced mandibular plane angle reported by Gungor and Turkkahraman. 9 Two findings of the present study are particularly striking, and include the noted shorter maxilla and significantly reduced maxillary protrusion frequently demonstrating an inter-relationship with the observed symptoms, the most frequent of which was mal-eruption of the maxillary canine(s). By the summary of the results in Table I, it may be concluded that it was relatively common for more than one symptom related to maxillary dental and occlusal development to be identified in a single patient, although such a combination was not observed in all patients. Due to a large variation in the combination of symptoms observed, no distinct combination pattern could be established. (The selection of subjects for this study represented the frequency of the various anomalies and should not be interpreted as demonstrating the frequency of the anomaly in an unselected population.)

An interesting finding was that the individuals exhibiting aplasia of maxillary incisors did not demonstrate ectopia of the maxillary canines. In a résumé of the clinical problems of ectopic canines, 29 it has been suggested that the lateral maxillary incisor guides the maxillary canine in its eruption path. The findings of the present study further suggested that, where no lateral incisor exists, the maxillary canine is able to erupt, though the limits of the examination in the present report did not allow evaluation of the position of the erupted canines.

The report illustrates that even though the occlusal and dental anomalies of the maxilla were often associated with skeletal jaw discrepancies, no involvement of cranial base flexure could be demonstrated, which supports the findings of Woodworth et al. 3

The results of the cephalometric analysis of patients exhibiting anomalies of formation and/or eruption of maxillary teeth or malocclusion related to the maxilla demonstrated a clear and typical pattern.
Table IIIh. Comparison between groups of the experimental material and the control material in terms of exhibiting a reduced vertical overbite in the incisor region.

|                      | Control / Max def (reduced OB) | Control | s.d. | Reduced OB | s.d. | t   | Sig. |
|----------------------|--------------------------------|---------|------|------------|------|-----|------|
| Control / Max def    | N=122                          |         |      | N=21       |      |     |      |
| Sagittal jaw         |                                |         |      |            |      |     |      |
| relationship         |                                | 1       |      | A-N-Pg     | 1.31 | 2.86| 0.68 | 3.37 | 0.896| ns   |
|                      |                                | 2       |      | A-N-B      | 2.56 | 2.44| 1.60 | 2.94 | 1.583| ns   |
|                      |                                | 3       |      | WITS       | 1.30 | 2.63| -1.9 | 3.56 | 3.015| ***  |
| Jaw prognathism      |                                | 4       |      | Maxillary (A) | 81.72| 3.69| 78.68| 3.46 | 4.085| ***  |
|                      |                                | 5       |      | Mandibular (Pg) | 80.42| 4.00| 77.99| 3.87 | 2.927| **   |
|                      |                                | 6       |      | Mandibular (B) | 79.16| 3.80| 77.07| 3.82 | 2.571| *    |
| Vertical relationship|                                | 7       |      | Vertical jaw | 21.18| 5.81| 28.99| 5.96 | 6.187| ***  |
|                      |                                | 8       |      | Maxillary | 8.88 | 2.92| 7.70 | 2.94 | 1.877| *    |
|                      |                                | 9       |      | Mandibular | 30.05| 6.08| 36.67| 5.11 | 5.876| ***  |
| Mandibular morphology|                                | 10      |      | Beta angle | 22.13| 2.94| 19.65| 2.32 | 4.785| ***  |
| Cranial base         |                                | 11      |      | N-S-ba     | 130.85| 5.23| 131.33| 3.87 | 0.536| ns   |
| Jaw length           |                                | 12      |      | Maxillary length | 53.68| 3.04| 48.84| 4.69 | 5.123| ***  |

Table IIIi. Comparison between groups of the experimental material and the control material in terms of exhibiting problems with maxillary canine eruption.

|                      | Control / Max def (canine eruption) | Control | s.d. | Canine eruption | s.d. | t   | Sig. |
|----------------------|-------------------------------------|---------|------|-----------------|------|-----|------|
| Control / Max def    | N=122                               |         |      | N=113           |      |     |      |
| Sagittal jaw         |                                | 1       |      | A-N-Pg         | 1.31 | 2.86| 1.96 | 2.97 | 1.707| ns   |
| relationship         |                                | 2       |      | A-N-B          | 2.56 | 2.44| 2.90 | 2.59 | 1.044| ns   |
|                      |                                | 3       |      | WITS           | 1.05 | 2.63| -2.4 | 5.62 | 5.941| ***  |
| Jaw prognathism      |                                | 4       |      | Maxillary (A)  | 81.72| 3.69| 79.94| 3.91 | 3.578| ***  |
|                      |                                | 5       |      | Mandibular (Pg)| 80.42| 4.00| 77.98| 3.73 | 4.816| ***  |
|                      |                                | 6       |      | Mandibular (B) | 79.16| 3.80| 77.04| 3.66 | 4.346| ***  |
| Vertical relationship|                                | 7       |      | Vertical jaw   | 21.18| 5.81| 27.15| 6.67 | 7.275| ***  |
|                      |                                | 8       |      | Maxillary      | 8.88 | 2.92| 7.59 | 3.12 | 3.257| ***  |
|                      |                                | 9       |      | Mandibular     | 30.05| 6.08| 34.74| 6.21 | 5.833| ***  |
| Mandibular morphology|                                | 10      |      | Beta angle     | 22.13| 2.94| 20.10| 2.99 | 5.239| ***  |
| Cranial base         |                                | 11      |      | N-S-ba         | 130.85| 5.23| 130.99| 4.22 | 0.223| ns   |
| Jaw length           |                                | 12      |      | Maxillary length | 53.68| 3.04| 54.39| 49.18| 0.154| ns   |
MAXILLARY DEFICIENCY SYNDROME (var. 4). This finding explains the observation of clinical crowding in many of these cases. The second important finding was the mandibular morphology observed in the experimental group expressed by the significantly reduced $\beta$ angle, indicating a relatively low ramus height. According to Björk and Skieller, this suggests a mandibular growth pattern characterised by a vertical growth displacement of the mandibular symphysis. The mandibular morphology observed in the present study corresponded to the increased vertical jaw relationship (var. 7) typified by the steeply inclined mandibular plane and reflected some of the clinical problems encountered in the management of this type of patient.

In recognition that a comparison between the entire group of patients against a control group could ‘mask’ individual variations in morphology connected with single anomalies of maxillary development, the material was divided on the basis of the nine factors described. This process accepts that some ‘crossover’ of related traits of maxillary deficiency could not be avoided. The results showed a level of agreement with the findings from the total material, although some small differences were observed. Of the subjects with missing maxillary lateral incisors, the observation of the accompanying maxillary retrognathism together with a clear reduction in the length of the maxilla (palatal plane) corroborated the findings of Lisson and Scholtes. This group demonstrated the least differences in skeletal relationships when compared with control material and similarly identified no difference in mandibular morphology. The group selected on the basis of the identification of peg-shaped lateral incisors showed a similar pattern although with a higher vertical jaw relationship.

In relation to the incisal relationship, a distinction was made between anterior crossbite in which one, two or three maxillary incisors occluded lingually to the mandibular incisors, and negative overjet in which all four maxillary incisors occluded lingually. The rationale behind the differentiation was that an anterior crossbite was considered more likely to be of dento-alveolar origin whereas a negative overjet was more likely to be skeletal in nature. The findings of the present study tended to support this hypothesis, with a more prognathic mandible observed in the case of a negative overjet.

Open bite malocclusions revealed an increased sagittal jaw relationship, although with a slight maxillary retrognathism and a more pronounced mandibular retrognathism, accompanied by a reduced $\beta$ angle suggesting an unfavorable mandibular growth pattern. Clinical experience has shown that many patients exhibiting symptoms of maxillary deficiency have an occlusion, which in the vertical plane is characterised by a minimal vertical overbite. Patients exhibiting a vertical overbite of less than 1.0 mm (although not showing an open bite) were selected and their data in Table IIIh reveals that these subjects displayed the characteristics of maxillary deficient subjects, negative jaw relationship (Wits), bi-maxillary retrognathism, a short maxillary length and a low $\beta$ angle. This important clinical finding suggests that the presentation of a minimal vertical overbite could indicate the presence of a maxillary deficiency with corresponding skeletal and growth implications.

In a summary of the cephalometric findings of patients exhibiting individual traits of maxillary deficiency, it may be appreciated that, even though many of the described anomalies seem very ‘localised’ to individual teeth or areas of the occlusion, these deviations from normal usually involved skeletal structures in both sagittal and vertical planes as well as the growth pattern of the mandible.

Conclusions

(1) Mal-eruption of the one or both of the maxillary canines was the most commonly observed anomaly (44.66%), whereas a lateral crossbite (39.13%) was also frequently observed. Other anomalies were also regularly observed, although less frequently.

(2) While 62% of the subjects exhibited only one of the described criteria indicating maxillary deficiency, the remaining 38% exhibited a combination of two or more of the symptoms, although no particular combination could be established.

(3) The cephalometric analysis frequently revealed a facial pattern characterised by bi-maxillary retrognathism as well as an increased vertical jaw relationship often accompanied by local anomalies. The length of the palate (anterior nasal spine – posterior nasal spine) was usually significantly reduced and a mandibular morphology with low ramus height suggested a morphological pattern which necessitated care in vertical mechanical control. A lateral crossbite
and problems involving maxillary canine eruption were the symptoms most likely to be related to other forms of anomaly.

(4) The clinical observation of a reduced vertical incisal overbite was indicative of a more comprehensive maxillary dysplasia, which was supported by the findings of the present study.

(5) The inter-relationship between skeletal and dental features concerning maxillary development reported in this study supports the hypothesis that anomalies of maxillary development can be regarded as a syndrome-like expression of maxillary deficiency.

(6) The findings of frequent maxillary retrognathism, a short maxilla and a possible vertical growth pattern are factors that have clinical consequence and should be taken into consideration in connection with orthodontic therapy.

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