Overbite depth and anteroposterior dysplasia indicators: the relationship between occlusal and skeletal patterns using the receiver operating characteristic (ROC) analysis

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SUMMARY This study was carried out to investigate the validity of the overbite depth indicator (ODI) and the anteroposterior dysplasia indicator (APDI), based on the cephalometric analysis of 122 Caucasians selected at random for assessment of vertical and sagittal relationships. Considering the occlusion, the sample was divided into three classifications in the sagittal component: 36 cases of neutrocclusion, 54 cases of distocclusion, and 34 cases of mesiocclusion. The sample was also categorized according to the overbite relationship: 54 cases of normal overbite, 34 cases of open bite, and 34 cases of deep overbite.

In the sagittal component analysis, the APDI measurement resulted in significant differences between the neutrocclusion, distocclusion, and mesiocclusion groups. In the vertical component analysis, the ODI significantly distinguished between the normal and deep overbite groups, and the open bite and deep overbite groups, but not between the normal overbite and the open bite groups. A receiver operating characteristic (ROC) analysis showed that the APDI matched the anteroposterior molar relationship in 88 per cent, and the ODI matched the amount of incisor overbite in 81 per cent.

Introduction

A lateral cephalometric radiograph reveals details of skeletal and dental relationships that are not observed on clinical examination (Graber and Vanarsdall, 1994). Differential diagnosis is essential because similar malocclusions may be analogous, but not homologous due to different skeletal patterns (Graber and Vanarsdall, 1994). While the angle ANB or the denture base relationship (Wits appraisal) were devised to determine the sagittal jaw discrepancies, some authors question the ability of these measurements to describe these relationships (Oktay, 1991; Foley *et al.*, 1997; Čelar *et al.*, 1998). The same controversy exists with the vertical

dimension (Frost *et al.*, 1980; Fields *et al.*, 1984; Graber and Vanarsdall, 1994). No single cephalometric measurement separates normal from vertically abnormal patients (Fields *et al.*, 1984). A combination of cephalometric measurements could provide more information as the sum of inter-planar angles is more appropriate for the comprehension of skeletal features (Kim and Vietas, 1978; Han and Kim, 1998).

In the past, two component cephalometric measurements were introduced for the differential diagnosis of malocclusions: the overbite depth indicator (ODI; Kim, 1974) and the anteroposterior dysplasia indicator (APDI; Kim and Vietas, 1978). Consisting of two angular measurements, the ODI describes the tendency

of an existing dentoskeletal pattern towards open or deep bite. The APDI consists of three angles and is used to assess a given sagittal relationship. Former studies on the ODI and APDI only applied global tests, and did not test each study group against the other (Kim, 1974, 1979; Kim and Vietas, 1978).

The purpose of the present investigation was to answer the following questions: Do significant differences exist for the ODI and its components in subjects assigned to study groups according to the incisor overbite? Do significant differences exist for the APDI and its components when the subjects are assigned to groups according to the Angle classification?

Subjects and methods

This study evaluated clinical and cephalometric data of 122 Caucasians selected at random. The sample consisted of 44 males and 78 females aged from 7 to 33 years (mean 13 ± 5.8 years; median and mode, 12 years). The subjects were first-time patients from two private orthodontic offices and five public dental centres in Vienna, Austria. The offices were chosen according to demographic data and informed consent was obtained.

Each patient examined had the following records taken: a clinical examination, a lateral cephalometric headfilm, and mounted dental casts. The patients were assigned to three groups according to the overbite and the Angle classification measured on the dental cast:

1. The overbite was measured on the cast in millimetres with dial callipers accurate to 0.1 mm. For evaluation of the ODI, the patient's overbite placed him/her in one of three test groups: the open bite group (zero or plus mm open bite, $n = 34$), the deep bite group (overbite > 3 mm, $n = 34$), and the normal overbite group (overbite between 0.1 and 3 mm, $n = 54$).
2. For evaluation of the APDI, the molar relationship placed the patient into one of three sagittal test groups: the neutrocclusion group ($n = 36$), the mesiocclusion group ($n = 32$), the distocclusion group ($n = 54$).

Further criteria used for the assignment included the incisor overjet and the canine relationship.

Cephalometric measurements

The ODI is the scalar sum of two angles and read without unit: (i) the angle formed by the A–B plane and the mandibular plane (MP), and (ii) the angle formed by the palatal plane (PP) and the Frankfort horizontal plane (FH). When the PP slopes upwards and forwards to the FH, the measurement is read as a negative angle. When the PP slopes downwards and forwards in relation to the FH, the measurement is read as a positive angle (Figure 1).

The APDI is the scalar sum of three angles: (i) the angle formed by the FH and the line connecting nasion and pogonion (N–Pg), (ii) the angle formed by the A–B line and N–Pg, and (iii) the angle formed by the PP and the FH. If the A–B line is rotated clockwise to the N–Pg, the measurement will be read negatively. Conversely, a positive value will result in counter-clockwise rotation of the A–B line (Figure 1).

Each of the four investigators who separately collected the data evaluated a part of the sample (clinical examination, cast analysis, cephalometric tracing). To check for systematic error
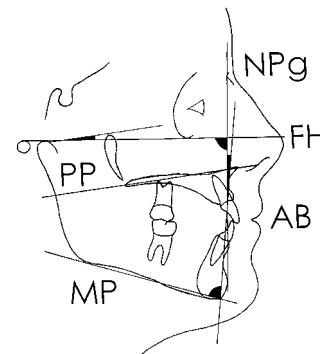

Figure 1 Cephalometric tracing with the angular measurements used for ODI and APDI. Note the negative value for the angles FH–PP and AB–NPg in this illustration. ODI = AB–MP angle ± FH–PP angle; APDI = FH–NPg angle ± AB–NPg angle ± FH–PP angle.

(inter- and intra-examiner), 10 lateral cephalograms were selected randomly. These cephalograms were traced by all four investigators and retraced after 6 months. The mean method errors for all four angles averaged 1 degree according to Dahlberg's formula (Dahlberg, 1940).

Statistical evaluation

Descriptive statistics for ODI and APDI included mean, SD, median, maximum, and minimum values. The Wilk–Shapiro test was applied to check for normal distribution. A one-way analysis of variance was used to compare the mean values for the ODI and the APDI for each study group. *Post hoc* multiple comparisons were carried out using Tukey's test. Significant difference was considered if $P < 0.05$.

As the ODI and the APDI are understood as diagnostic tests, a further statistical evaluation was applied independent of the analysis of variance: the receiver operating characteristic method (ROC). The ROC calculates the association between sensitivity and specificity for each value of interest. Sensitivity is the proportion of positives identified correctly by a diagnostic test, and specificity the proportion of negatives identified correctly (Altman, 1997). In a graph, the sensitivity is plotted on the vertical axis against 1—specificity on the horizontal axis, varying the values of the groups for the parameter of interest (Guggenmoos-Holzmann and Wernecke, 1996; Altman, 1997). The ROC curve represents the true-positive rate versus the false-positive rate. The performance of a diagnostic test can be evaluated by calculating the area under the curve expressed as a proportion of the total possible area. An area of 1 represents a perfect test and an area of 0.5 indicates a test that performs no better than chance. More efficient diagnostic tests are represented by ROC curves, which lie closest to the top left corner of the graph and which therefore occupy a larger percentage of the entire graph area. In other words, the area under the ROC curve is an index of accuracy.

Within the ROC analysis, the ODIs of the open bite group were compared with those of the normal overbite group and those of the deep bite group were compared with the normal overbite group. For the APDI, the distocclusion group was compared with the neutrocclusion group and the mesiocclusion group with the neutrocclusion group. Further ROC calculations compared the ODIs of the open bite group with those of the deep bite group, and the APDIs of the distocclusion group with the APDIs of the mesiocclusion group. The SAS Statistical Package® (SAS Institute Inc., Cary, NC, USA) was used for all computations.

Results

The ODI measurements demonstrated the following means and SD: 65.5 ± 8.8 in the open bite group, 67.7 ± 8 in the normal overbite group, and 75.3 ± 5.5 in the deep bite group. Table 1 shows these results and the mean $\pm$ SD of

Table 1 Mean $\pm$ SD, significant (*), and not significant (NS) inter-group differences of the ODI, and its two angular components FH–PP and AB–MP according to Tukey's test ($P < 0.05$), the ODI's area under the ROC curve, and Kim's (1974) values.

	ODI	FH-PP	AB-MP	ROC of ODI	ODI (Kim 1974)
OB (n = 34)	65.5 ± 8.8	–2 ± 4.3	66.7 ± 6.9		65.5 ± 6.1
NB (n = 54)	67.7 ± 8	–2.4 ± 3.2	70.2 ± 7.6		74.5 ± 6.1
DB (n = 34)	75.3 ± 5.5	–1.7 ± 3.7	76.8 ± 5.5		77.7 ± 6.6
NB versus OB	NS	NS	NS	0.6	
NB versus DB	*	NS	*	0.78	
OB versus DB	*	NS	*	0.81	

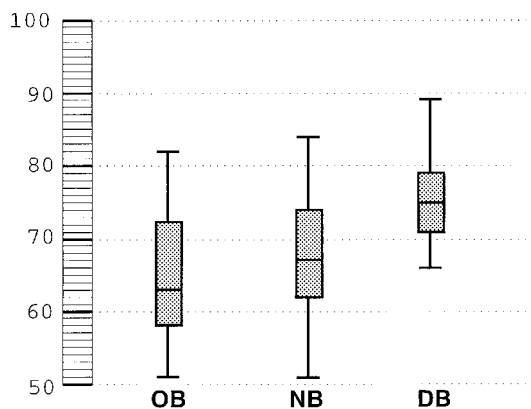OB, open bite group; NB, normal overbite group; DB, deep bite group.

Figure 2 Box-and-whisker plots of descriptive statistics (minimum, maximum, median, and upper and lower quartiles) for the ODI in the open bite group (OB), the normal overbite group (NB), and the deep bite group (DB).

overbite group compared with the deep bite group, the area under the ROC curve was 0.78 (Table 1, Figure 3). The ODIs of the open bite group versus those of the deep bite group resulted in an area under the ROC curve of 0.81. The 95 per cent confidence intervals for the mean differences in ODI are shown in Table 2.

The APDI measurements averaged 78 ± 5.8 in the distocclusion group, 81.2 ± 6 in the neutrocclusion group, and 88 ± 5.6 in the mesi-occlusion group. Mean $\pm$ SD of the three angular components are shown in Table 3. Descriptive statistics for the APDI are given in Figure 4 as a box-and-whisker plot. The APDI values were significantly different between all groups, while its components did not show consistent significant difference between the groups (Tukey's Student test, Table 3).

both angular components of the ODI. Further descriptive statistics for the ODI are shown in Figure 2 as a box-and-whisker plot for each group. Testing one group against the other, significant inter-group differences were found in the ODIs and angles AB–MP, except between the open and normal bite groups; the angle FH–PP was not significantly different between the groups (Table 1; Tukey's Student test, $P < 0.05$).

Testing the ODIs of the normal overbite group against those of the open bite group, the area under the ROC curve yielded 0.6. For the normal

Table 2 The 95 per cent confidence intervals for the ODI mean differences, and upper and lower confidence limits between the three vertical groups.

ODI	lcl < dbm < ucl
NB versus OB	1.8 < 2.2 < 6.2
NB versus DB	3.7 < 7.7 < 11.7
OB versus DB	5.4 < 9.8 < 14.3

lcl, lower confidence limit; dbm, difference between means; ucl, upper confidence limit; OB, open bite group; NB, normal overbite group; DB, deep bite group.
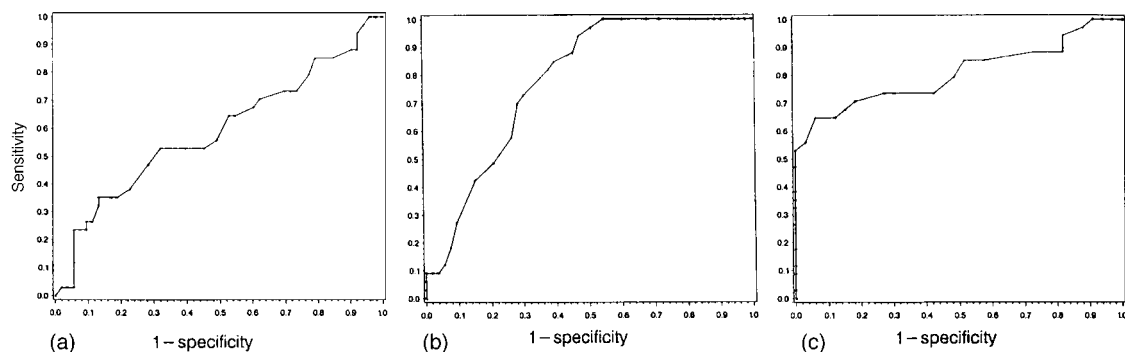

Figure 3 (a–c) Receiver operating characteristic curves of the ODI. (a) Open bite group versus normal overbite group (OB–NB). (b) Deep bite group versus normal overbite group (DB–NB). (c) Deep bite group versus open bite group (DB–OB).

Table 3 Means ± SD, significant (*) and not significant (NS) inter-group differences of APDI and its three angular components (FH–PP, FH–NPg, AB–NPg) according to Tukey's test ($P < 0.05$), the APDI's area under the ROC curve, and the values of Kim and Vietas (1978).

	APDI	FH-PP	FH-NPg	AB-NPg	ROC of APDI	APDI (Kim and Vietas, 1978)
D (n = 54)	78 ± 5.8	–2.4 ± 3.9	87.2 ± 3.3	–7 ± 3.9		75.2 ± 4.3
N (n = 36)	81.2 ± 6	–0.8 ± 2.8	87.1 ± 3.5	–5.3 ± 4.6		80.4 ± 4.5
M (n = 32)	88 ± 5.6	–3 ± 3.7	90.3 ± 4.6	0.7 ± 3.3		88.5 ± 6.7
N versus D	*	NS	NS	NS	0.66	
N versus M	*	*	*	*	0.79	
D versus M	*	NS	*	*	0.88	

D, distocclusion group; N, neutrocclusion group; M, mesiocclusion group.
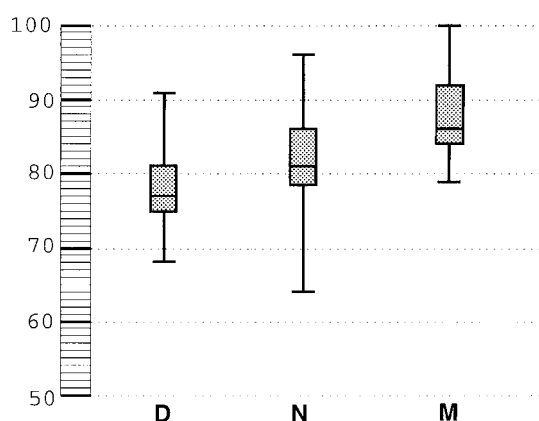

Figure 4 Box-and-whisker plots of descriptive statistics (minimum, maximum, median, and upper and lower quartiles) for the APDI in the distocclusion (D), neutrocclusion (N), and mesiocclusion groups (M).

The ROC computations for the APDI resulted in an area under the curve of 0.66 when testing the distocclusion group versus the neutrocclusion group, and 0.79 for the mesiocclusion group versus the neutrocclusion group. Testing the mesiocclusion versus the distocclusion group, the area under the ROC curve was 0.88 (Figure 5). The 95 per cent confidence intervals for the mean differences in APDI are reported in Table 4.

Discussion

The work of Sassouni and Nanda (1964) highlighted the necessity of considering anteroposterior and vertical measurements within an analysis of the lateral headfilm. This obligation has been met by the APDI and ODI. In the present study
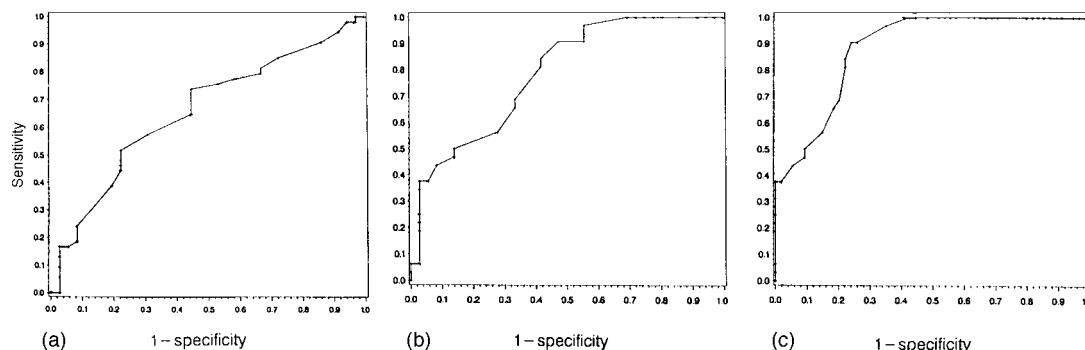

Figure 5 (a–c) Receiver operating characteristic curves of the APDI. (a) Neutrocclusion group versus distocclusion group (N–D). (b) Neutrocclusion group versus mesiocclusion group (N–M). (c) Distocclusion group versus mesiocclusion group (D–M).

Table 4 The 95 per cent confidence intervals for the APDI mean differences, and upper and lower confidence limits between the three anteroposterior groups.

APDI	lcl < dbm < ucl
N versus D	0.2 < 3.2 < 6.2
N versus M	3.5 < 6.8 < 10.2
D versus M	6.9 < 10 < 13.1

lcl, lower confidence limit; dbm, difference between means; ucl, upper confidence limit; D, distocclusion group; N, neutrocclusion group; M, mesiocclusion group.

the statistical analysis revealed the significant differences between Class I, Class II, and Class III malocclusions in terms of the APDI. For the ODI, the statistical analysis found significant differences between subjects with deep bite and those with an open bite, and also between subjects with normal overbite and those with a deep bite, but no significant difference was found between the normal overbite and open bite groups.

The ODI and APDI means of the present study mostly agree with those published by Kim (1974), and Kim and Vietas (1978). The only gross exception was found between the ODIs of the normal overbite groups (Table 1), which was the same as the significance of inter-group difference. While Kim (1974) defined normal overbite as between 0.5 and 4 mm, the present study defined normal overbite from 0.1 to 3 mm, according to the literature (Schwarz, 1951; Posselt and Franzen, 1960; Ai, 1962; Andrews, 1972; Solberg and Clark, 1974; Schulze, 1993; Schmuth and Vardimon, 1994). In the opinion of the authors, it appears reasonable to attribute the 4 mm overbite to a deep rather than to a normal bite group.

Evaluated by ROC curves, a modified ODI had the highest diagnostic value in distinguishing open bite from any positive overbite (Wardlaw et al., 1992). Comparison of that study with the present investigation must consider (i) the modification of the ODI (Frankfort horizontal was replaced by the S–N plane as Wardlaw et al.

(1992) intended to avoid an error into the identification of orbitale), and (ii) the assignment of the subjects in only two groups (open and non-open bite). It may be speculated that both studies allow the following conclusion: The ODI is able to distinguish the deep and open bite, but not between an overbite of 0.1–3 mm and open bite.

The ODI as a diagnostic measurement was questioned on the basis of a sample of five subjects in a case report article (Nahoum, 1975). However, other investigators have found the ODI and APDI to have the highest correlation for description of vertical and sagittal relationships among up to 15 commonly used cephalometric measurements (Kim, 1974; Kim and Vietas, 1978; Oktay, 1991; Wardlaw et al., 1992; Han and Kim, 1998).

Previous research on the ODI and APDI and the results of the present study indicate that the judgement of skeletal relationships benefits from component angular measurements (Kim, 1974; Kim and Vietas, 1978; Wardlaw et al., 1992). This is shown for the facial plane angle, the denture plane angle, and the angle FH–PP. For example, mandibular retrognathism may be expressed as a low value to the single angle FH–NPg. The more severe the Class II, the greater is the angulation between the A–B line and the N–Pg line, and a low APDI value results (emphasized by a negative angle AB–NPg). Using the APDI, its significant differences between the normo-, disto-, and mesiocclusion groups was superior to some single angular measurements of the APDI (insignificant differences between the normo- and distocclusion, and the disto- and mesiocclusion groups). Thus, the APDI provided more diagnostic evidence than one of its component measurements alone.

Vertical relationships are covered by the ODI within the cephalometric analysis. Regarding the two components of the ODI separately, the angle AB–MP showed significant inter-group differences to the same extent as the ODI in the present study. The orientation of the PP to the FH plane played an important role only in the assessment of the individual malocclusion. In an individual with open bite, a negative FH–PP angle decreases the ODI value and complicates therapy.

In medicine, a diagnostic indicator is used to determine the presence or absence of a sign, a disease, or the probability to be ill. An indicator should differentiate between two conditions (Zweig and Campbell, 1993). For example, the creatine phosphokinase isoenzyme confirms the diagnosis of an acute myocardial infarction. In this instance a so-called 'cut-off' value exists on which a diagnosis is based. Demanding such a cut-off value for an orthodontic diagnosis is unworkable since the question of an orthodontic diagnostic is never a faultless 'Yes' or 'No'. Variations in the dentofacial complex are rarely produced by a single factor (Kim and Vietas, 1978; Fields *et al.*, 1984). Wardlaw *et al.* (1992) demonstrated that a single cut-off value was of little use in orthodontic diagnosis. They found that the calculation with the ROC method was far more useful in discriminating the diagnostic value of various cephalometric measurements.

In order to substantiate a link between skeletal pattern and occlusion in the present study, the results of the ROC analysis expressed the probability that an individual with a low ODI value had a greater chance of an open bite and *vice versa* for the deep bite. The same held true for the APDI and the Angle classification: the higher the APDI value, the greater the probability of a Class III malocclusion and/or skeletal pattern, and *vice versa* for the Class II.

If the non-significant difference for the ODI between the normal bite and the open bite group (Tukey's test), the probability of having a higher value in the normal overbite group was 60 per cent in terms of the ROC. In detail, the ROC calculation showed that the vertical skeletal pattern was consistent with the extent of the overbite in 81 per cent. Nineteen per cent did not show this characteristic. It may be speculated that the alveolar bone and/or the axial inclination of the dentition contribute to this diagnostic confusion if an ODI typical of a skeletal open bite appears with a deep incisal overbite. On the other hand, an individual with a high ODI value, typical of a skeletal deep bite, may present with a dental open bite due to habits or an extremely protruded incisor inclination. Such inconsistencies between the skeletal pattern and the amount of overbite must be taken into account for

individual treatment planning: a complex treatment of the malocclusion must be expected. This argument was substantiated by Meyers (1992), who tested the relationship between craniofacial structures and occlusion. He found a higher correlation between the variation in antero-posterior skeletal structure and that in sagittal occlusion than between the variation in vertical skeletal structure and that in vertical occlusion.

In the ROC procedure for the APDI, the consistency of the skeletal pattern with the amount of molar relationship was almost as high as 90 per cent. However, there are still patients with a skeletal Class III pattern and a distocclusion. In these instances, the Angle classification does not match the inherent skeletal morphology. On the other hand, individuals with a Class I molar relationship and a low APDI value may be allocated to a skeletal Class II group. In treating such so-called Class I malocclusions, one should, for example, avoid mechanics that shift the molar Class I to a Class II, for example, by a backward rotation of the mandible. Neglecting such a relationship could produce an unexpected iatrogenic Class II.

Several authors have found evidence of a non-existing homogenous Class I (Nanda, 1990; Harris and Johnson, 1991; Dibbets, 1996; Enlow and Hans, 1996). This Class I could have any of several anterior relationships: deep overbite, open bite, crossbite, rotations, etc., and they are all still Class I molar. To be thorough, these patients need a better distinguishing characteristic, which would relate their malocclusions to their inherent skeletal pattern. Enlow and Hans (1996) stated: 'This is a clinically most relevant point but it has almost never been a factor in most clinical and research studies'. Their statement was confirmed by the ROC analysis when testing the normal overbite group and the neutrocclusion group, respectively, against the other two groups in the present study. Most malocclusions exist because of the variations in the skeletal pattern. In most instances, malocclusions mirror the skeletal pattern in which they are found, i.e. Class II molar relationships exist in Class II skeletal patterns. In those malocclusions that do not mirror their skeletal pattern, component measurements such as the

ODI and the APDI could preclude treatment complications, e.g. a low ODI indicates the risk of opening the bite during treatment.

Another advantage of these component measurements is the use of angles fairly stable during growth. In the longitudinal growth studies of Riolo *et al.* (1974), Bhatia and Leighton (1993), and Bishara *et al.* (1997), the angles used for the ODI and the APDI did not show significant changes during growth with the exception of the facial plane angle. Thus, the assessment of malocclusions becomes independent of individual age.

In the present study, mounted casts were used to simulate the intra-oral clinical chairside examination, which is dominated by the molar relationship, and the amount of overjet and overbite. As stated by Han and Kim (1998), there is no cephalometric measurement widely accepted that displays the skeletal configuration of a malocclusion, while occlusal relationships are commonly used diagnostic parameters.

Derived from individuals seeking orthodontic consultation, the data for the neutrocclusion and normal overbite groups might be biased in the present study. Further research should be undertaken to establish 'norm values' derived from a randomized ideal occlusion sample, matching the six keys of normal occlusion of Andrews (1972). However, such a project might interfere with ethical commitments to radiographic hygiene.

Conclusions

1. In the vertical component analysis, the ODI differentiated significantly between the deep bite and normal overbite groups, and between the deep bite and open bite groups. The normal overbite was defined as being between 0.1 and 3 mm.
2. In the sagittal component analysis, the APDI resulted in significant group differences between all three Angle classes.
3. The lower the ODI value, the greater the chance of a skeletal open bite and *vice versa* for the deep bite. This was consistent with the incisor overbite in 81 per cent of subjects.
4. A high APDI indicated a skeletal Class III pattern, a low number showed a Class II. This

was consistent with the molar relationship in 88 per cent.
5. Lack of agreement between ODI and incisor overbite, or between APDI and molar relationship, may be indicative of a complex treatment of the malocclusion.

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References

Ai M 1962 A study of masticatory movement at the incision inferius. Journal of the Japanese Prosthodontic Society 6: 164–200

Altman D G 1997 Practical statistics for medical research. Chapman & Hall, London

Andrews L F 1972 The six keys to normal occlusion. American Journal of Orthodontics 62: 296–309

Bhatia S N, Leighton B C 1993 A manual of facial growth. A computer analysis of longitudinal cephalometric growth data. Oxford University Press, Oxford

Bishara S E, Jakobsen J R, Vorhies B, Bayati P 1997 Changes in dentofacial structures in untreated Class II division 1 and normal subjects: a longitudinal study. Angle Orthodontist 67: 55–67

Čelar A G, Freudenthaler J W, Čelar R M, Jonke E, Schneider B 1998 The Denture Frame Analysis: an additional diagnostic tool. European Journal of Orthodontics 20: 579–587

Dahlberg G 1940 Statistical methods for medical and biological students. Interscience, New York

Dibbets J M H 1996 Morphological associations between the Angle classes. European Journal of Orthodontics 18: 111–118

Enlow D H, Hans M G 1996 Essentials of facial growth. W B Saunders, Philadelphia

Fields H W, Proffit W R, Nixon W L, Philips C, Stanek E 1984 Facial pattern differences in long-faced children

and adults. American Journal of Orthodontics 85: 217–223

Foley T F, Stirling D L, Hall Scott J 1997 The reliability of three sagittal reference planes in the assessment of Class II treatment. American Journal of Orthodontics and Dentofacial Orthopedics 112: 320–329

Frost D E, Fonseca R J, Turvey T A, Hall D J 1980 Cephalometric diagnosis and surgical-orthodontic correction of apertognathia. American Journal of Orthodontics 78: 657–669

Graber T M, Vanarsdall Jr R L 1994 Orthodontics. Current principles and techniques. C V Mosby, St Louis

Guggenmoos-Holzmann I, Wernecke K D 1996 Medizinische Statistik. Blackwell Wissenschafts-Verlag, Berlin

Han U K, Kim Y H 1998 Determination of Class II and Class III skeletal patterns: receiver operating characteristic (ROC) analysis on various cephalometric measurements. American Journal of Orthodontics and Dentofacial Orthopedics 113: 538–545

Harris E F, Johnson M G 1991 Heritability of craniometric and occlusal variables: a longitudinal sib analysis. American Journal of Orthodontics and Dentofacial Orthopedics 99: 258–268

Kim Y H 1974 Overbite depth indicator with particular reference to anterior open-bite. American Journal of Orthodontics 65: 586–611

Kim Y H 1979 A comparative cephalometric study of Class II, division 1 nonextraction and extraction cases. Angle Orthodontist 49: 77–84

Kim Y H, Vietas J J 1978 Anteroposterior dysplasia indicator: an adjunct to cephalometric differential diagnosis. American Journal of Orthodontics 73: 619–633

Meyers D M 1992 A multivariate analysis of the relations between craniofacial structure and occlusion with DiPaolo's quadrilateral measures. American Journal of Orthodontics and Dentofacial Orthopedics 102: 52–61

Nahoum H I 1975 Anterior open-bite: a cephalometric analysis and suggested treatment procedures. American Journal of Orthodontics 67: 513–521

Nanda S K 1990 Growth patterns in subjects with long and short faces. American Journal of Orthodontics and Dentofacial Orthopedics 98: 247–268

Oktay H 1991 A comparison of ANB, WITS, AF-BF, and APDI measurements. American Journal of Orthodontics and Dentofacial Orthopedics 99: 122–128

Posselt U, Franzen G 1960 Registration of the condyle path inclination by intraoral wax records: variations in three instruments. Journal of Prosthetic Dentistry 10: 441–454

Riolo M L, Moyers R E, McNamara Jr J A, Stuart Hunter W 1974 An atlas of craniofacial growth. Cephalometric standards from the University School growth study, Monograph No. 2, Center for Cranofacial Growth and Development. University of Michigan, Ann Arbor

Sassouni V, Nanda S 1964 Analysis of dentofacial vertical proportions. American Journal of Orthodontics 50: 801–823

Schmuth G P F, Vardimon A D 1994 Kieferorthopädie. Thieme, Stuttgart

Schulze C 1993 Lehrbuch der Kieferorthopädie Band I. Quintessenz, Berlin

Schwarz A M 1951 Lehrgang der Gebißregelung. Band I: Untersuchungsgang (Diagnostik). Urban & Schwarzenberg, Wien

Solberg W K, Clark G T 1974 Reproducibility of molded condylar controls with an intraoral registration method. Part I. Simulated movement. Journal of Prosthetic Dentistry 32: 520–528

Wardlaw D W, Smith R J, Hertweck D W, Hildebolt C F 1992 Cephalometrics of anterior open bite: a receiver operating characteristic (ROC) analysis. American Journal of Orthodontics and Dentofacial Orthopedics 101: 234–243

Zweig M H, Campbell G 1993 Receiver-operating characteristic (ROC) plots: a functional evaluation tool in clinical medicine. Clinical Chemistry 39: 561–577