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Compensation for vertical dysplasia and its clinical application

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SUMMARY The purpose of this study was to quantitatively evaluate skeletal and dental compensation in patients with vertical skeletal dysplasias and to determine which dentoalveolar parameters compensate for vertical jaw discrepancies. Cephalometric analyses were performed on pre-treatment lateral cephalographs of 186 orthodontic patients (120 females and 66 males; mean age 15 years 11 months) who met the selection criteria. SN–MP angle was used to classify the facial patterns as: hyperdivergent > 36 degrees, normo = 28–36 degrees, and hypo < 28 degrees. Analysis of variance (ANOVA) was used to determine statistical differences between the means in the three vertical facial types. To evaluate dental compensation quantitatively, correlation analyses were performed to find associations between skeletal and dental parameters. To further elucidate the compensatory nature of the lower incisors, regression analyses and scattergrams were obtained, with SN–MP as a measure of the vertical skeletal discrepancy.

ANOVA showed statistically significant differences for most of the skeletal variables, but only for lower incisor height and inclination among the dentoalveolar parameters. Correlation analyses demonstrated significant relationships between various skeletal variables. LI–MP showed a negative relationship with SN–MP, whereas LAMdH demonstrated a positive linear relationship with SN–MP. Among all dentoalveolar heights, UAMxH showed the weakest, and LAMdH the strongest, associations with skeletal parameters. The variability in dentoalveolar compensation therefore demands individualized diagnosis and treatment planning. LAMdH and LI–MP parameters were the most likely, whereas UAMxH was the least likely parameter to compensate for vertical dysplasia.

Introduction

Vertical facial form is an important element of orthodontic assessment. Large variations are found in the vertical dimension and these affect the clinician's approach to successful diagnosis, treatment planning, and mechanics (Nanda, 1988).

Discrepancies between dentoalveolar morphology and the underlying vertical skeletal relationship might result in a deep or open bite (Beckmann *et al*., 1998a; Karlsen, 1994; Arat and Rubenduz, 2005). The fundamental differences between open and deep bites are therefore skeletal as well as dental in nature. Thus an open bite, a normal overbite, or a deep bite can all occur in long faces (Schendel *et al*., 1976; Fields *et al*., 1984; Dung and Smith, 1988). On the other hand, subjects with a normal face height can also have a normal overbite or an open bite (Karlsen, 1994). According to Kuitert *et al.* (2006), lower face height and overbite are unrelated.

Dentoalveolar compensation is 'a system which can attain and maintain a normal overbite with varying skeletal patterns' (Solow, 1980). Dentoalveolar compensation has two main components in the vertical dimension: the first concerns the vertical development of the basal and dentoalveolar heights and the second affects incisor inclination (Nahoum *et al*., 1972; Solow, 1980; Lopez-Gavito *et al*., 1985; Katsaros and Berg, 1993; Handelman, 1996; Beckmann *et al*., 1998a,b). A deep bite in some patients may be the result of increased incisor height or reduced molar height; thus, the treatment approach should be different in each of these cases (Schudy, 1968).

It is also possible for different malocclusions to be expressed with similar skeletal problems, depending on whether or not dentoalveolar compensation has occurred. This may be why there is disagreement in the literature over the relationship between the anterior dentoalveolar dimensions, lower face height, and overbite (Kuitert *et al*., 2006).

The pattern of vertical facial development is established in the mixed dentition (Nanda, 1988). In a growing child, differential eruption can mask vertical skeletal dysplasias. Maxillary molars are considered to be the primary 'bite openers' and the mandibular incisors, the primary 'bite closers' (Schudy, 1968). Directing dentoalveolar growth is accepted as a standard treatment for managing such skeletal deviations (Arat and Rubenduz, 2005). Although inhibiting growth of anterior face height may result in an improved skeletal pattern in hyperdivergent patients, augmenting posterior face height may be an equally important goal (Horn, 1992; Buschang and Martins, 1998).

In adults, however, true intrusion versus extrusion, or a surgical approach, may be required to mask or treat a dysplasia. Although surgery may be the only way to alter large vertical skeletal discrepancies, orthodontists will inevitably be faced with the situation of attempting a non-surgical camouflage approach in borderline patients with vertical skeletal dysplasia (Sankey *et al*., 2000). Delineation of the limits of orthodontic tooth movement prior to the start of treatment is thus extremely beneficial (Ten Hoeve and Mulie, 1976; Handelman, 1996).

Several studies have been conducted regarding the efficiency of dentoalveolar compensation (Nahoum *et al*., 1972; Schendel *et al*., 1976; Lopez-Gavito *et al*., 1985; Janson *et al*., 1994; Handelman, 1996; Beckmann *et al*., 1998a,b; Kuitert *et al*., 2006). Some authors have divided their subjects according to the extent of overbite (Nahoum *et al*., 1972; Lopez-Gavito *et al*., 1985; Beckmann *et al*., 1998a), some according to face height (Janson *et al*., 1994; Beckmann *et al*., 1998b), and others according to SN–MP (Kuitert *et al*., 2006). The results, however, are not consistent for those dentoalveolar parameters that compensate most readily and rely solely on the concept of the extent of the open/deep bite in subjects with varying vertical facial forms is not sufficient.

Therefore, this study was conducted to quantitatively evaluate skeletal and dental compensation in patients with vertical skeletal dysplasia.

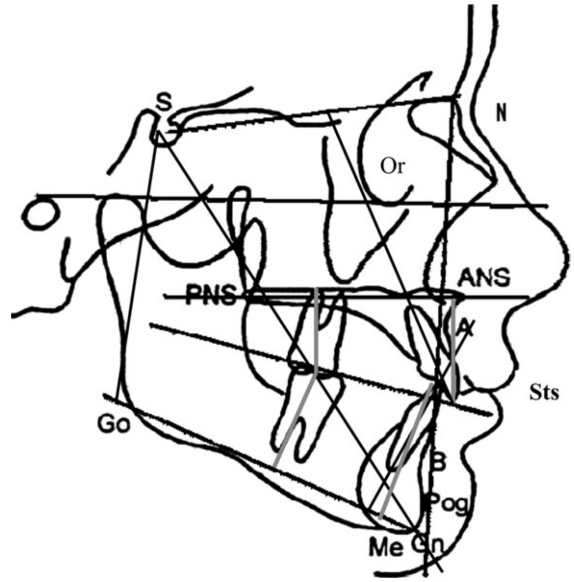

Figure 1 Cephalometric landmarks and planes used to assess dentoalveolar compensation. Landmarks: nasion (N), the junction of the frontonasal suture at the most posterior point on the curve at the bridge of the nose; Sella (S), The centre of the pituitary fossa of the sphenoid bone determined by inspection; Orbitale (Or), the lowest point on the bony orbit; Porion (P), the midpoint of a line connecting the most superior point of the radiopacity generated between by the two ear rods of the cephalostat; Anterior nasal spine (ANS), the most anterior point on the bony hard palate; Posterior nasal spine (PNS), the most posterior point on the bony hard palate; Point A (A), the most posterior point on the curve of the maxilla between ANS and supradentale; Gonion (Go), the midpoint of the angle of the mandible; Gnathion (Gn), the most anterior and inferior point on symphyseal outline; Pogonion (Pog), the most anterior point on the contour of the bony chin; Menton (Me), the most inferior point on the symphyseal outline; Point B (B), the point most posterior to a line from infradentale to Pog on the anterior surface of the symphyseal outline of the mandible; Stomion superius (Sts), tThe lowest midline point of the upper lip. Planes SN plane, sella–nasion plane; FH plane, Frankfort horizontal plane, the line connecting Po to Or; Palatal plane, A line connecting ANS and PNS; Mandibular plane, A line joining Go and Gn.

Materials and methods

This was a cross sectional study carried out on the pre-treatment lateral cephalographs of orthodontic patients who attended clinics at the Aga Khan University Hospital, Karachi, from 1 January 2005 to 31 December 2006. Patients with erupted incisors and first molars (aged 11.5–45 years) who had good quality orthodontic records were included in the study. Those with craniofacial disorders, facial asymmetries, a history of previous orthodontic treatment, or a history of trauma were excluded. Cephalograms of 186 patients (120 females and 66 males), who met the selection criteria were traced manually by one author (NA). The cephalometric landmarks and planes used are shown in Figure 1. The mandibular plane angle (SN–MP) was used to classify facial patterns as: hyperdivergent greater than 36 degrees, normodivergent equal to 28–36 degrees, and hypodivergent less than 28 degrees (Ceylan and Eroz, 2001). Eleven angular and 10 linear variables were measured to assess the skeletal pattern and the amount of dentoalveolar compensation (Table 1). To establish the tracing and measurement errors, 10 randomly selected lateral cephalographs were re-traced and re-measured by the same author after a 2 week interval.

Statistical analysis

Descriptive statistics were calculated to identify the mean for each parameter and the mean in each of the three vertical facial types. Analysis of variance (ANOVA) was used to compare the three groups. A *post hoc* Bonferroni test was applied to account for multiple comparisons between the groups. To evaluate skeletal compensation quantitatively, linear bivariate correlation analyses were performed to establish the associations between the skeletal parameters (SN–MP, FMA, *y*-axis, PFH, LAFH, TAFH, SN–PP, gonial angle, and symphyseal height). Pearson's correlation coefficients were used to determine the associations between skeletal (ANB, SN–MP, FMA, *y*-axis, PFH, LAFH, TAFH, SN–PP, gonial angle, and symphyseal height) and dental parameters (IIA, UI–SN, LI–MP, UAMxH, UPMxH, LAMdH, LPMdH, IS, and OB). To further elucidate the compensatory nature of the lower incisors, regression analysis and scattergrams were produced with SN–MP as a measure of vertical skeletal discrepancy. A Wilcoxon signed-rank test was used for assessment of intraexaminer reliability. Statistical analyses were performed with the Statistical Package for the Social Sciences for Windows 14.0 (SPSS Inc, Chicago, Illinois, USA). For all statistical analyses, $P \leq 0.05$ was considered significant.

Table 1 Cephalometric angular and linear measurements.

SNA: inward angle towards the cranium between the NA line and the sella–nasion (SN) plane
SNB: inward angle toward the cranium between the NB line and the SN plane
ANB: angle between the NA and NB lines, obtained by subtracting SNB from SNA
SN plane to mandibular plane angle (SN–MP): angle between the SN plane and the mandibular plane (MP)
Frankfort mandibular plane angle (FMA): angle between the FH plane and MP
Posterior face height (PFH): line connecting sella with gonion
Total anterior face height (TAFH): from nasion to menton (Me)
Lower anterior face height (LAFH): from ANS to Me
y-axis: acute angle formed between the sella gnathion line and FH plane
Gonial angle (GA): angle formed between the ramus of the mandible and the MP
Symphyseal height (SH): distance between infradentale and Me
Incisor stomion (IS): the visible amount of the upper central incisor in a relaxed lip posture; distance between stomion superius and upper incisal edge
IIA (interincisal angle): angle measured between the extension of the maxillary and mandibular incisor long axis line; the most posterior angle is measured
Maxillary incisor to SN plane (UI–SN): most inferior inward angle formed by the extension of the long axis of the maxillary incisor to the SN plane
Mandibular incisor to mandibular plane (LI–MP): long axis of the mandibular incisor to the MP; the most inward angle toward the body of the mandible is measured
Sella–nasion plane to palatal plane (SN–PP): angle between the SN plane and palatal plane
Sella–nasion to occlusal plane angle (SN–OP): angle between the SN plane and occlusal plane
Overbite: vertical overlap of upper and lower incisors
Upper anterior maxillary height (UAMxH): the perpendicular distance from the maxillary central incisor edge projected at right angles to the palatal plane (mm)
Lower anterior mandibular height (LAMdH): the perpendicular distance from the mandibular central incisor edge projected at right angles to the MP (mm)
Upper posterior maxillary height (UPMxH): the perpendicular distance from the mesiodistal midpoint of the maxillary molar, at the level of the functional occlusal plane to palatal plane
Lower posterior mandibular height (LPMdH): the perpendicular distance from the mesiodistal midpoint of the mandibular molar, at the level of the functional occlusal plane to the MP (mm)

Results

Intraexaminer reliability was confirmed by statistically insignificant differences ($P > 0.05$) between the first and second cephalometric measurements.

Of the 186 subjects, $n = 84$ (45%) were classified as normodivergent, $n = 54$ (29%) as hypodivergent, and $n = 48$ (26%) as hyperdivergent. Their mean age was 15 years 11 months (range: 11 years 7 months to 42 years 4 months). Table 2 shows the mean value for each parameter in the three groups and for the whole group, together with the results of the ANOVA. Statistically significant differences were found for the majority of the skeletal variables. Among the dentoalveolar parameters, only lower incisor height and inclination showed a statistically significant difference ($P = 0.036$ and $P = 0.013$, respectively). Multiple comparisons of the means between the three groups showed significant intergroup differences for all skeletal variables. For PFH, there were significant differences between all three groups, but lower anterior and the total anterior face heights showed significant differences only between the hypo- and hyperdivergent groups, with the normodivergent group showing no significant difference when compared with the other two groups. No statistically significant differences were found between the means for UI–SN, SH, IS, UPMxH, UAMxH, and LPMdH. LI–MP and LAMdH both showed statistical differences only between the hypo- and hyperdivergent groups. Palatal plane inclination was found to be statistically different between the hypodivergent subjects and the other two groups.

Correlation coefficients between the various skeletal variables (SN–MP, FMA, *y*-axis, PFH, LAFH, SN–PP, gonial angle, and symphyseal height) are shown in Table 3. Significant positive and negative linear relationships were found between the various skeletal variables, showing intrinsic craniofacial compensation. Table 4 shows the results of the correlation analyses between the various dental and skeletal variables. For vertical facial pattern (as represented by SN–MP), there was a negative linear relationship with lower incisor inclination ($r = -0.293$), whereas a positive linear relationship ($r = 0.224$) for lower incisor height. Anterior and posterior face heights were significantly associated with all dentoalveolar heights except UAMxH. Face height did not show any significant associations with incisor inclination. Anterior face height showed a stronger relationship with posterior than with anterior dental heights (UPMxH: $r = 0.534$, LPMdH: $r = 0.305$). Gonial angle showed significant negative linear associations with posterior dental heights, the value being greatest for lower posterior dental height ($r = -0.650$). Among all dentoalveolar heights, UAMxH showed the weakest association and LAMdH, the strongest association with the skeletal parameters. The highest correlation coefficient ($r = -0.650$) was found between LPMdH and gonial angle, followed by UPMxH and PFH ($r = 0.534$). For lower incisor inclination, the highest correlation was for

Table 2 Mean values and standard deviations (SD) for the measured parameters and results of ANOVA.

Parameters	Total mean ± SD (*N* = 186)	Hypodivergent ± SD (*N* = 54)	Normodivergent ± SD (*N* = 84)	Hyperdivergent ± SD (*N* = 48)	*P* value
Sella–nasion point A	81.66 ± 3.8	83.44 ± 3.3	81.99 ± 3.5	79.10 ± 3.6	<0.001
Sella–nasion point B	77.45 ± 3.9	79.81 ± 3.5	77.70 ± 3.2	74.35 ± 3.4	<0.001
ANB	4.31 ± 2.7	3.62 ± 3.1	4.46 ± 2.5	4.81 ± 2.5	0.071
Sella–nasion to mandibular plane	31.76 ± 2.4	24.16 ± 2.3	32.01 ± 3	39.89± 2.8	<0.001
Frankfort to mandibular plane	24.49 ± 6.2	18.00 ± 3.8	24.64 ± 3.2	31.52 ± 4.1	<0.001
y-axis	61.95 ± 4.6	59.35 ± 3.7	61.53 ± 4.0	65.62 ± 4.4	<0.001
Posterior face height	75.90 ± 6.8	78.86 ± 6.9	75.93 ± 6.3	72.54 ± 6.3	<0.001
Lower anterior face height	66.33 ± 7.6	64.00 ± 5.0	67.03 ± 6.9	67.75 ± 10.4	0.025
Total anterior face height	115.81 ± 13.7	111.75 ± 15.8	116.57 ± 14.2	119.04 ± 8.7	0.022
Sella–nasion to occlusal plane	17.50 ± 7.3	13.85 ± 4.3	17.81 ± 9.1	21.08 ± 3.6	<0.001
Gonial angle	124.97 ± 9.8	120.61 ± 6.7	125.20 ± 11.5	129.50 ± 7.2	<0.001
Symphyseal height	31.37 ± 4.4	30.53 ± 3.6	31.50 ± 4.8	32.10 ± 4.6	0.201
SN to palatal plane	7.88 ± 3.4	6.16 ± 2.5	8.20 ± 3.6	9.25 ± 3.3	<0.001
Interincisal angle	119.30 ± 11.2	121.98 ± 13.4	119.16 ± 10.1	116.54 ± 9.5	0.049
Upper anterior maxillary height	28.58 ± 15.2	26.53 ± 3.2	29.86 ± 25.4	28.62 ± 2.8	0.544
Upper posterior maxillary height	21.25 ± 3.7	21.38 ± 3.1	21.31 ± 4.4	21.33 ± 3.1	0.980
Lower anterior mandibular height	38.88 ± 4.4	38.05 ± 3.1	38.62 ± 5.3	40.25± 3.6	0.036
Lower posterior mandibular height	29.63 ± 7.8	28.94 ± 3.1	29.97 ± 11.1	29.81 ± 3.5	0.744
Upper incisor to sella–nasion	107.68 ± 10.4	109.63 ± 7.6	106.86 ± 12.9	106.91 ± 7.6	0.265
Incisor to mandibular plane	99.81 ± 10.8	103.22 ± 9.4	99.15 ± 12.2	97.14 ± 8.5	0.013
Incisor stomion	4.88 ± 2.1	4.31 ± 1.8	5.05 ± 2.6	5.21 ± 2.1	0.069
Overjet	5.32 ± 3.9	4.85 ± 3.5	5.46 ± 4.3	5.60 ± 3.6	0.574
Overbite	3.87 ± 6.5	3.99 ± 2.7	3.29 ± 2.5	4.77 ± 12.0	0.458

Table 3 Correlation analyses between skeletal parameters.

	SN–MP	FMA	*y*-axis	PFH	LAFH	TAFH	SN–PP	SN–OP	Gonial angle	SH
SN–MP	1	0.887**	0.515**	−0.389**	0.224**	0.208**	0.337**	0.400**	0.389**	0.139
FMA		1	0.587**	−0.361**	0.146*	0.191**	0.207**	0.287**	0.456**	0.115
y-axis			1	−0.123	0.215**	0.110	0.130	0.238**	0.177*	0.121
PFH				1	0.446**	0.363**	−0.140	−0.190**	−0.411**	0.179*
LAFH					1	0.468**	−0.117	0.037	−0.002	0.394**
TAFH						1	0.082	0.101	0.017	0.292**
SN–PP							1	0.304**	0.028	−0.045
SN–OP								1	0.06	0.017**
Gonial<									1	0.325**
SH										1

*$P < 0.05$, **$P < 0.01$

SN–MP, and for lower incisor height with LAFH (r = 0.469).

The results of the linear regressions performed to further evaluate the compensatory nature of the lower incisors are shown in Table 5. The standardized coefficient showed a negative association for LI–MP and a positive association for LAMdH so for every 1 degree increase in SN–MP the lower incisors retroclined by 0.29 degrees and increased in height by 0.22 mm. Figure 2 shows the scattergrams using SN–MP as a measure of vertical jaw discrepancy; the strength of association can be visualized in the best fit line.

Discussion

Posterior dental heights tend to be responsible for the facial morphological pattern, whereas anterior dental heights tend to be determinants of overbite (Huang, 2002). Consideration of only overbite can be misleading, due to the possibility of dentoalveolar compensation having occurred, and may lead to inappropriate treatment mechanics being used (Schudy, 1968). Hyperdivergent profiles are considered challenging due to the extrusive nature of the treatment mechanics, the high relapse rate, and the thin labial and lingual cortical plates. Successful treatment therefore demands prudent diagnosis and careful consideration of treatment mechanics.

Table 4 Correlation analyses between dental and skeletal parameters.

	IIA	UI-SN	LI-MP	UAMxH	UPMxH	LAMdH	LPMdH	IS	Overjet	Overbite
ANB	−0.295**	−0.114**	0.268**	0.017	0.008	0.032	0.058	0.204	0.401	0.137
SN–MP	−0.200**	−0.093	−0.293**	0.053	0.026	0.224**	0.092	0.127	0.060	0.046
FMA	−0.212**	−0.061	−0.252**	0.086	−0.016	0.195**	0.026	0.134	0.051	0.051
y-axis	−0.0232**	−0.079	0.095	0.108	0.075	0.214**	0.013	0.106	0.216**	0.055
PFH	0.134	0.099	−0.057	0.009	0.534**	0.279**	0.305**	−0.024	−0.070	−0.059
LAFH	−0.024	0.022	−0.063	0.066	0.502**	0.469**	0.226**	0.150*	0.025	−0.054
TAFH	0.080	0.377**	−0.163*	0.032	0.390**	0.335**	0.209**	0.102	−0.078	−0.009
SN–PP	0.103	−0.268**	−0.134	−0.048	−0.092	−0.147*	0.045	−0.034	−0.068	0.138
SH	0.006	−0.018	0.202**	0.077	0.219**	0.547**	−0.173*	0.073	−0.011	−0.009
Gonial angle	−0.007	0.006	0.151*	0.030	−0.311**	0.074	−0.650**	0.015	0.027	−0.003

$^*P < 0.05$, $^{**}P < 0.01$.

Table 5 Results of regression analyses.

		Unstandardized coefficients		Standardized coefficients	*t*	Significance
		B	Standard error	Beta		
Dependent variable: incisor to mandibular plane inclination						
Model 1	Constant	115.192	3.775		30.511	<0.001
	Sella–nasion to mandibular plane	−0.484	0.116	−0.293	−4.158	<0.001
Dependent variable: lower anterior mandibular height						
Model 1	Constant	34.025	1.590		21.394	<0.001
	Sella–nasion to mandibular plane	0.153	0.049	0.224	3.116	0.002

Control of the vertical dimension is probably the most important factor in the correction of such malocclusions.

This study was undertaken to determine the adaptation of the vertical skeletal and dentoalveolar parameters to the vertical base relationship. The skeletal parameters demonstrated significant correlations and intrinsic craniofacial compensation, mainly occurring in the mandibular ramus, palatal plane, gonial angle, and occlusal plane, which is in agreement with the findings of Enlow *et al.* (1971). The significant correlation of SN–MP with SN–PP (r = 0.337), SN–OP (r = 0.400), gonial angle (r = 0.389), PFH (r = −0.389), and *y*-axis (r = 0.515) indicate a rotational growth pattern of the palatal, occlusal, and mandibular planes. High-pull headgear may be used in the treatment of such hyperdivergent profiles; however, this requires close monitoring as it can cause clockwise palatal plane rotation, which may lead to aggravation of an anterior gummy smile and compromised smile aesthetics.

The results of the ANOVA for the dental parameters demonstrated significant differences only for lower incisor inclination and height between the three vertical face types. Correlation analyses between the dental and skeletal variables showed significant associations for some of the dental variables and therefore compensation in these parameters. All dental height measurements, except for upper anterior dental height, were significantly correlated with the skeletal parameters and showed compensation. Weak correlation coefficients for upper anterior dental height were an unexpected finding and this suggests limited maxillary anterior dental compensation. Upper incisor inclination showed a significant positive association only with total anterior face height, i.e. incisor proclination as the total face height increases. This has a bite opening effect and may also pose a risk factor for root resorption and periodontal problems (Handelman, 1996). Elucidation of pre-treatment upper incisor inclination is therefore essential. This parameter is also pivotal in smile aesthetics; therefore, its relationship with overall face height must be considered during treatment planning. Handelman (1996) suggested that antero-posterior movement of the roots should be limited in hyperdivergent patients. According to the present study, maxillary incisor inclination has only a low correlation with overbite and a positive correlation with TAFH, suggesting that compensatory retroclination of the maxillary incisors, in order to maintain overbite, did not occur in this patient sample. A possible reason could be the lack of lip seal and therefore lip pressure in the increased face height patients, resulting in proclination of the incisors. The findings are in agreement with those of Nahoum *et al.* (1972), but in contrast to other studies (Subtelny and

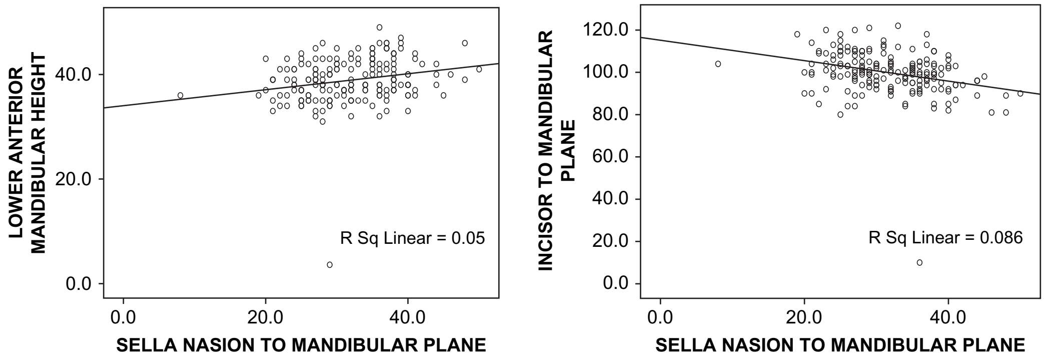

Figure 2 The relationship between the lower incisors and the extent of vertical skeletal dysplasia: SN–MP to LAMdH and LI–MP.

Sakuda, 1964; Ellis and McNamara, 1984; Lopez-Gavito *et al*., 1985; Janson *et al*., 1994), which showed dental compensation for this parameter. During camouflage treatment of such patients, retroclination helps as it will improve overbite as well as anterior aesthetics. UAMxH in this study showed weak associations with SN–MP. Again, this implies minimal dental compensation. The height of the upper incisors can therefore be increased, within limits, to camouflage the vertical incisor relationship in hyperdivergent subjects.

Gonial angle showed a negative linear relationship with posterior dental heights, i.e. a compensatory decrease in dental heights with increasing gonial angle. This results in a decrease in backward rotation of the mandible and therefore prevents the skeletal hyperdivergence worsening. This is in agreement with the results of Betzenberger *et al.* (1999). Some studies have found no change in posterior dental heights (Janson *et al*., 1994; Swlerenga *et al*., 1994), whereas others found an increased height in hyperdivergent subjects (Schendel *et al*., 1976; Ellis and McNamara, 1984; Fields *et al*., 1984; Lopez-Gavito *et al*., 1985; Janson *et al*., 1994; Beckmann *et al*., 1998a). In the current study, posterior dental heights were significantly correlated with anterior face height and this is a favourable compensation. In hyperdivergent subjects, if an increased posterior dental height is found, treatment should be aimed at its reduction by orthodontic mechanics (intrusion). On the other hand, if the posterior height is within normal limits, the likely cause of hyperdivergence is tilting of posterior palatal plane and a combined orthodontic orthognathic treatment approach may be required.

Lower anterior dental height and inclination demonstrated significant associations with many of the skeletal variables and seems to be the parameter most likely to compensate for varying vertical skeletal relationships. SN–MP showed a negative relationship with LI–MP and a positive relationship with LAMdH, which means that as the vertical skeletal relationship increases, the lower incisors compensate by retroclining and by increasing their height, so the tendency for an open bite is reduced. Although the association was moderate, the biological limitations for lower incisors are reduced so that even a slight change in inclination as well as height can affect prognosis, stability, and aesthetics. According to Schudy (1968), mandibular incisor height is variable and the same extent of overbite in different patients does not necessarily mean that the mandibular incisors are the same height. Kuitert *et al.* (2006) and Beckmann *et al*. (1998b) found an increase, whereas Ellis and McNamara (1984), Lopez-Gavito *et al.* (1985), and Subtelny and Sakuda (1964) found no difference in this parameter in hyperdivergent patients. Thus, the overall relationship (both height and inclination) to skeletal hyperdivergence and overbite still seems variable in nature. If insufficient compensation is found in lower incisor height and inclination, further compensation can be successfully carried out to treat the malocclusion without impairing stability or aesthetics. Although the results of this study show the uncompensated nature of the upper incisors especially in terms of a change in height, extrusion of the upper incisors for the purpose of open bite correction can adversely affect smile aesthetics.

Overbite did not show a significant association with changing vertical dimensions. This apparent disharmony between overbite and varying vertical dimensions confirms the natural dentoalveolar compensation being sufficient in some cases but not in others. In agreement with the results of Kuitert *et al.* (2006), maxillary and mandibular molar heights were not found to be significantly related to overbite.

There is clearly variable dentoalveolar compensation and this differs from patient to patient. Therefore, dentoskeletal features should be studied in every individual; not all patients can be treated alike because not all faces are alike. Assessment of dentoalveolar heights is important when treating any malocclusion so that the mechanics are not contrary to biological needs. The uncompensated parameters can be compensated as a means to camouflage the malocclusion, whereas when there is pre-existing compensation, such mechanics should be avoided as they lead to poor prognosis, stability, and aesthetics. The results of the present study show the lower incisors to be the most compensated dentoalveolar parameter for different vertical skeletal dysplasias; their pre-treatment height and inclination are of importance with regards to the stability of any changes planned.

Insufficient data is available regarding vertical adaptation of the dentition in relation to different sagittal jaw relationships. Interestingly, in this study, dental heights did not show any statistically significant association with ANB; only incisor inclination demonstrated a significant association. This is in agreement with results of Janson *et al.* (1994). Dentoalveolar heights and their relationship with sagittal and vertical dimension is a dynamic relationship and dental heights can be different in both sagittal and vertical skeletal dysplasias.

Population standards for molar and incisor heights should be considered in every patient. Evaluation of the characteristics of the malocclusion should be undertaken throughout treatment in an attempt to elucidate the effects of orthodontic treatment in compensated and non-compensated high angle malocclusion subjects.

Conclusions

The results of the study show that:

1. LAMdH and LI–MP are the most likely parameters to compensate for different vertical skeletal dysplasias and
2. UAMxH showed the least tendency to change according to different vertical skeletal relationships.

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