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Quantum of incisal compensation in skeletal class III malocclusion: a cross-sectional study

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Abstract (J Korean Assoc Oral Maxillofac Surg 2024;50:265-272)

Objectives: Skeletal class III malocclusion presents either with maxillary retrognathism, mandibular excess, or a combination. Dentoalveolar compensations occur with maxillary incisor proclination and mandibular incisor retroclination. The aim of this study is to quantify the amount of incisal compensation in class III skeletal malocclusion and correlate it to the severity of the skeletal base.

Materials and Methods: Eleven angular and 7 linear cephalometric measurements were digitized from 57 patients. Axial inclination of the upper and lower incisors was evaluated for compensation. Pearson's correlation coefficient was used to determine the dentoalveolar parameter among those measuring upper and lower incisor position and inclination that correlated most highly with the severity of class III. Linear regression analysis was used to identify the quantum of the incisal compensation.

Results: Upper incisors were proclined and placed anteriorly. However, correlation analysis suggested a less responsive incisor with progressive change in skeletal base. Lower incisors began to compensate only as the severity of class III increased. For every degree of reduction of ANB angle from normal, the incisor mandibular plane angle (IMPA) and L1-GoMe decreased by 0.79° and the L1-GoGn decreased by 0.81°.

Conclusion: The upper incisors contributed more to compensation compared to the lower incisors in a class III skeletal base. As class III severity increased, the upper incisor compensation decreased while that of lower incisors increased. For every degree of reduction in ANB angle, the IMPA and L1-GoMe decreased by 0.79° and the L1-GoGn decreased by 0.81°.

Key words: Malocclusion, Angle class III, Compensation, Regression analysis

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I. Introduction

Malocclusion is defined as an abnormal occlusion in which teeth are not in a normal position in relation to adjacent teeth in the same jaw and/or the opposing teeth when the jaws are closed[1]. Skeletal class III malocclusion exists in three forms: maxillary retrognathism, mandibular excess, or a combination of both[2]. Any such disparities in the maxilla and/or mandible appear to be compensated for by the dentoalveolar segments to achieve a harmonious interarch relationship between the defective jaw bases. This is referred to as "dentoalveolar compensation".

Thus, dentoalveolar compensation refers to 'a system which attempts to maintain normal interarch relationship under varying jaw relationships'[3]. Goldsman[4] explained that when one facial dimension shows an obvious discrepancy, one or more of the other structures will be altered to minimize the effects of the dimensions displaying the obvious discrepancy. There are several factors that influence dentoalveolar compensation. These include the influence of the normal eruptive system, dental equilibrium, and the neighboring teeth[5].

However, there is a limit to the compensation, and that is what defines whether the teeth will be in normal occlusion despite a jaw mal-relationship or whether a malocclusion less severe than the jaw discrepancy will develop[6]. The pattern of dentoalveolar compensations observed in class III skeletal malocclusion caused by retrognathic maxilla is proclination

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of maxillary incisors in the sagittal plane and buccal tipping of maxillary molars in the transverse plane, whereas in a skeletal class III malocclusion due to a prognathic mandible, compensation involves retroclination of mandibular incisors in the sagittal plane and lingual tipping of mandibular molars in the transverse plane[7]. With regards to a combination class III malocclusion, the above-mentioned compensations may also appear in combination.

However, review of the literature suggests that such compensations do not always happen in the patterns described above, and one jaw might compensate more than the other[8,9]. Additionally, most, if not all, authors who have described dentoalveolar compensations in skeletal class III malocclusions have not quantified it. To the best of our knowledge, only a few studies have investigated the association between dentoalveolar compensation and skeletal base severity. The authors of these studies described the association between these two factors[9,10]. In more detail, Ishikawa et al.[9] studied incisal compensation in 44 adult females with either a class I or class III skeletal base based on the mean ANB angle of the Japanese population and concluded that incisal compensation tended to occur by labial tipping of upper incisors and lingual tipping of lower incisors. The magnitude of compensation was also specified in his study. However, it was exclusively studied in females and included both class I and class III skeletal bases. Mathapun and Charoemratrote[10] studied the incisor relation in class III malocclusion based on different positions of maxillary and mandibular jaw bases. They concluded that upper incisors showed no compensation in prognathic maxilla and only limited compensation even with progressive maxillary retrognathism. However, the magnitude of this compensation was not studied. Also, These studies did not address confounding entities like sex and race which might influence dentoalveolar compensation. As the etiology of class III malocclusion is multi factorial with contributions from genetic, ethnic, environmental, and habitual factors, the scale of compensation might vary across races, and applying the results of these studies to the general human population is not appropriate.

1. Aims

Our aims in this study were to quantify the amount of incisal compensation seen in the Indian population with skeletal class III malocclusions and correlate this with the severity of the skeletal base.

2. Objectives

(1) To determine whether the most altered/compensated dentoalveolar parameter was associated with the maxillary component or mandibular component
(2) To identify which dentoalveolar parameter compensated the most for changes in jaw discrepancies
(3) To identify if there are sex differences in incisal compensations

Evidence of the extent of compensation (linear or angular) either of maxillary or mandibular incisors in skeletal class III malocclusions would aid the orthodontist in planning the amount of decompensation required when planning an orthognathic surgical procedure. Knowledge of the extent of compensation would also improve camouflaged orthodontic mechanics in borderline skeletal class III cases.

II. Materials and Methods

This study was approved by the Institutional Ethics Committee of Sri Ramachandra Institute of Higher Education and Research (SRIHER) (CSP/21/DEC/103/613). This cross-sectional study was carried out using the pre-treatment lateral cephalograms of 57 orthodontic patients seen in the Department of Orthodontics and Dentofacial Orthopedics, Sri Ramachandra Institute of Higher Education and Research (SRIHER), Chennai, India. The written informed consent was waived due to the study's retrospective design.

1. Inclusion criteria

The criteria for selection were (1) patients with a class III skeletal base based on an ANB angle of less than 2° and (2) males and females of any age.

2. Exclusion criteria

The exclusion criteria were (1) class I or class II skeletal base (ANB>2°), (2) severe asymmetries, (3) craniofacial disorders, (4) patients who underwent previous orthodontic treatment, and (5) patients with musculoskeletal disorders.

3. Methodology

Lateral cephalograms of the 57 included patients were digitally traced using Dolphin Imaging software (ver. 11.0; Dolphin Imaging and Management Solutions).(Fig. 1) Eighteen

cephalometric parameters, comprising 12 angular measurements and seven linear parameters, were measured. Skeletal parameters measured were ANB, SNA, and SNB. Linear and angular measurements are described in Table 1.

4. Magnitude of compensation

Normative data for incisor inclination and position extracted from the literature were considered control data and hence this was a self-controlled study. The presence of dental compensation was calculated by subtracting the patient's axial inclination values from the ideal value for that parameter. For example, to estimate upper incisor compensation, the deviation in the upper incisors' axial inclination with regards to U1-NA (°) from normal was calculated as (patient's U1-NA (°)–22°). Similar formulae were applied to all parameters to evaluate upper incisor inclination. To estimate lower incisor compensation, the deviation in the lower incisor axial inclination from the normal with regards to L1-NB (°) was calculated using the formula (25°–patient's L1-NB (°)), and similar formulae were applied to the other lower incisor parameters. For parameters that had a range of normal values, such as the ones representing the upper and lower anterior axial inclination and position, the upper and lower limits were used to estimate the change in upper and lower incisor position and inclination, respectively. Similarly, the severity of class III malocclusions was calculated by subtracting the patient's ANB value from 2°. Only the quantum of change and not the sign was taken into consideration for further data analysis. Nine parameters were measured and recorded for upper and lower incisor inclinations.(Table 1)

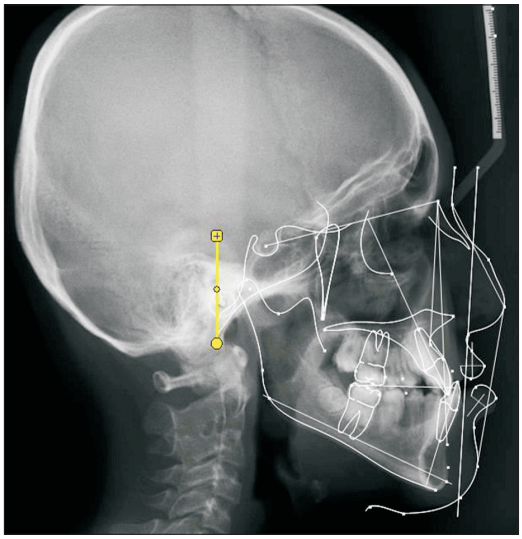

Fig. 1. Digital tracing using Dolphin Imaging software (ver. 11.0; Dolphin Imaging and Management Solutions).
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5. Statistical analysis

Descriptive and the measurements were tabulated in an

Table 1. List of cephalometric landmarks

Landmark	Definition
SNA angle (SNA)	The inferior posterior angle formed by the lines SN and NA
SNB angle (SNB)	The inferior posterior angle formed by the lines SN and NB
ANB angle (ANB)	Angle between the NA and NB lines, obtained by subtracting SNB from SNA
Maxillary incisor to NA plane (U1-NA) (mm)	Distance between the tip of the upper incisor and a line from N to point A
Maxillary incisor to NA plane (U1-NA) (°)	Angle formed by the intersection of the long axis of the upper central incisor and the line joining NA
Maxillary incisor to point A (U1-Point A)	Distance from the constructed point A perpendicular to the facial surface of the upper incisor
Maxillary incisor to SN plane (U1-SN)	Angle between the upper incisor axis and SN line, posteriorly
Maxillary incisor to palatal plane (U1-PP)	Angle between the upper incisor axis and palatal plane, anteriorly
Maxillary incisor to A-Pog (U1-APog) (mm)	Distance between the edge of the maxillary incisor and the line drawn from point A to pogonion
Maxillary incisor to A-Pog (U1-APog) (°)	Angle between the upper incisor axis and the A-Pog line
Maxillary incisor to N-Pog (U1-NPog)	Distance (vertical) of the upper incisor edge to the N-Pog line
Mandibular incisor to NB (L1-NB) (mm)	Distance between the tip of the mandibular incisor and a line from nasion to point B
Mandibular incisor to NB (L1-NB) (°)	Angle formed by the intersection of the long axis of the lower central incisor and the line joining NA
Mandibular incisor to mandibular plane (LI-MP)	Long axis of the mandibular incisor measured to the mandibular plane; the most inward angle toward the body of the mandible is measured.
Tweed's IMPA	Angle formed between the long axis of the lower incisor and the tangent to the lower border of the mandible
Mandibular incisor to A-Pog (L1-APog)	Distance between the edge of the mandibular incisor and the line drawn from point A to pogonion
Mandibular incisor to Go-Me (L1-GoMe)	Angle formed between the long axis of the lower incisor to the Go-Me plane
Mandibular incisor to Go-Gn (L1-GoGn)	Angle formed between the long axis of the lower incisor to the Go-Gn plane
Mandibular incisor to N-Pog (L1-NPog)	Distance (vertical) of the lower incisor edge to the N-Pog line

(IMPA: incisor mandibular plane angle)
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Microsoft Excel 2019 (Microsoft). Statistical Analysis were performed using IBM SPSS Statistics (ver. 20.0; IBM). Descriptive data were tabulated in an excel sheet, and subjected to tests of significance. In more detail, paired *t*-tests were applied to paired measurements to quantify the reproducibility of the measurements. Student's independent *t*-test was used to determine if there were differences in compensation between males and females. However, other confounding factors such as age, and growth pattern were not considered in the analyses. Means and standard deviations were calculated for the axial inclinations of the upper and lower incisors to evaluate the presence of compensation. Pearson's correlation coefficient was used to determine which dentoalveolar parameter among the ones measuring upper and lower incisor position and inclination correlated the most with the severity of class III malocclusions. The level of significance was set to $P<0.05$.

Linear regression analysis was used to identify the quantum of incisal compensation by considering the parameter that had the highest correlation as a dependent variable and the severity of the class III malocclusion (change in ANB) as the independent variable.

III. Results

Age of the included subjects ranged from 8-30 years with a mean age of 17.9±5.2 years. Thirty-three male and 24 female subjects were included in this study. Of 57 samples, 22 had a retrognathic maxilla and 35 had a prognathic mandible that contributed to their skeletal class III malocclusion. A total of 57 maxillary and mandibular incisor inclinations were studied. Means and standard deviations of all parameters used to assess upper and lower incisor inclination were calculated. (Table 2) Upper incisors proclined and were forwardly placed in the skeletal class III population. However, no change in lower incisor inclination in terms of compensation was noted.

To assess if the compensation that occurred was influenced by the skeletal base, we performed correlation analysis between the severity of the class III skeletal base and the deviation of the upper incisor values from the norms. Similarly, to assess if the compensation was related to the maxillary skeletal base only, correlation analysis was performed between the SNA and U1-NA values of the subjects.(Table 3)

With regards to Pearson's correlation coefficient, a positive correlation between the change in U1 inclination and the severity of ANB would mean that the former was influenced by the latter, indicating compensation. To extrapolate, if the ANB angle was reduced and if the upper incisors were proclined, then compensation was considered present. Similarly, a negative correlation between U1 inclination and SNA would mean the former was affected by the latter. We found that in terms of upper incisor inclination, U1-APog (liner and angular) (r=–0.321; P=0.015 and r=–0.509; $P<0.001$, respectively) and incisal edge to N-Pog line (r=–0.549; $P<0.001$) showed only a weak and moderately negative correlation with the severity of class III malocclusions, respectively.(Table 3) There was no significant correlation between U1-NA and SNA (r=0.003; P=0.980).(Table 3)

Table 2. Mean and SD of upper and lower incisor inclinations and positions

	Mean	SD
Upper incisor		
U1-NA (°)	36.75	7.80
U1-NA (mm)	8.15	4.04
U1-Point A (mm)	7.62	3.00
U1-SN (°)	120.60	9.28
U1-PP (°)	58.90	14.40
U1-APog (mm)	–1.56	4.11
U1-APog (°)	–0.13	9.92
Incisal edge to N-Pog (mm)	–0.46	4.86
Lower incisor		
L1-NB (°)	26.02	7.56
L1-NB (mm)	4.83	2.78
IMPA (°)	91.85	10.88
L1-GoGn (°)	95.91	7.10
L1-GoMe (°)	93.23	6.98
L1-NPog (mm)	6.06	3.38
L1-APog (°)	7.92	11.14

(SD: standard deviation, IMPA: incisor mandibular plane angle)
Refer to Table 1 for the definition of landmarks.
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Table 3. Pearson's correlation coefficients for the upper incisors

Parameter	Correlation (r)	P-value
Correlation between severity of the class III malocclusion and change in incisor inclination		
U1-NA	0.033	0.810
U1-NA	0.135	0.315
U1-Point A	0.089	0.509
U1-SN	–0.060	0.659
U1-PP	–0.148	0.273
U1-APog	–0.321	0.015*
U1-APog	–0.509	<0.001*
Incisal edge to N-Pog	–0.549	<0.001*
Correlation between SNA and upper incisor inclination		
U1-NA	0.003	0.980
U1-NA	–0.200	0.135
U1-Point A	–0.088	0.514
U1-SN	0.542	<0.001*
U1-PP	–0.195	0.146
U1-APog	–0.108	0.426
U1-APog	0.115	0.395
Incisal edge to N-Pog	–0.046	0.734

*$P<0.05$.
Refer to Table 1 for the definition of landmarks.
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Table 4. Pearson's correlation coefficient for lower incisors

Parameter	Correlation (*r*)	*P*-value
Correlation between severity of the class III malocclusion and change in incisor inclination		
L1-NB	–0.002	0.987
L1-NB	0.053	0.695
Tweed's IMPA	0.305	0.021*
L1-NPog	0.025	0.854
L1-APog line	–0.046	0.732
L1-APog	–0.283	0.033*
L1-Mand plane (Go-Me)	0.305	0.021*
L1-GoGn	0.311	0.018*
Correlation between SNB and lower incisor inclination		
L1-NB	–0.061	0.655
L1-NB	0.059	0.662
Tweed's IMPA	0.451	<0.001*
L1-NPog	0.043	0.753
L1-APog line	–0.019	0.886
L1-APog	–0.025	0.853
L1-Mand plane (Go-Me)	0.242	0.069
L1-GoGn	0.273	0.040

(IMPA: incisor mandibular plane angle)
*P<0.05.
Refer to Table 1 for the definition of landmarks.
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Table 5. Equation obtained using linear regression analysis

Parameter	Severity of class III	*P*-value
Tweed's IMPA	Y=0.797X–10.78	0.021
L1-GoMe	Y=0.797X–8.786	0.021
L1-GoGn	Y=0.81X–8.879	0.018

(IMPA: incisor mandibular plane angle)
Refer to Table 1 for the definition of landmarks.
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These results indicate that though the upper incisors of the study subjects were proclined, which can be seen from the mean values, there was no correlation between the quantum of upper incisor proclination and the quantum of class III skeletal base. In fact, the negative association seen for some of the parameters indicates that as the class III skeletal base increased, upper incisor compensation decreased.

Pearson correlation analysis of the L1 parameter and ANB severity showed weak positive correlations with regards to incisor mandibular plane angle (IMPA) (r=0.305; P=0.021), L1-GoGn (r=0.311, P=0.018), and L1-GoMe (r=0.305, P=0.021) and a weak negative correlation with L1-APog (r=–0.283, P=0.033).(Table 4)

These findings indicate that although the lower incisors were upright and did not compensate as much as the upper incisors (Table 2), the lower incisors began to compensate as the severity of the class III malocclusion increased, as evident from the significantly weak positive association. L1-NB and SNB were not significantly correlated (r=–0.061, P=0.655).

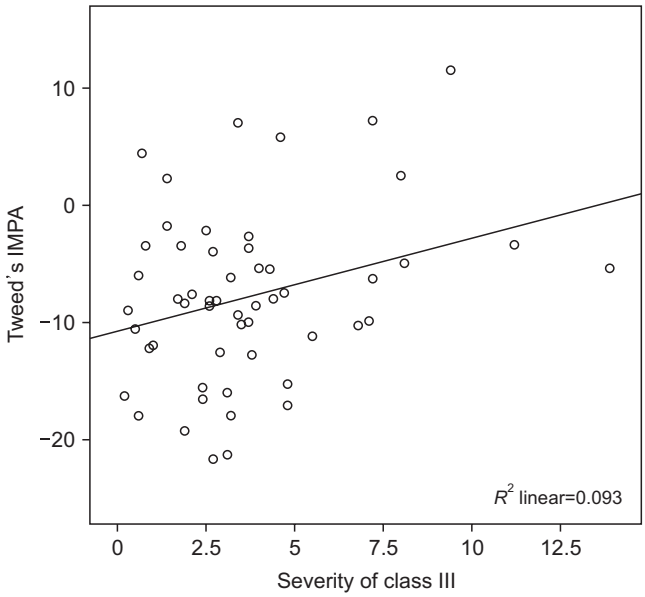

Fig. 2. Scatter plot between IMPA and severity of class III. (IMPA: incisor mandibular plane angle)
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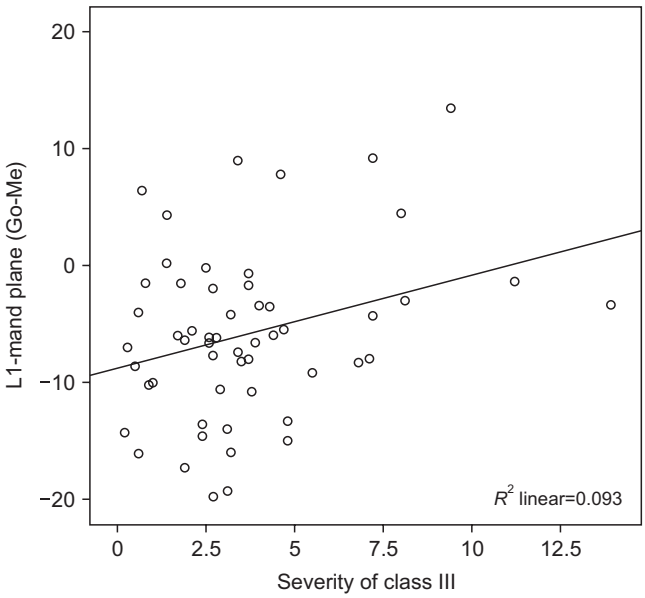

Fig. 3. Scatter plot between Go-Me and severity of class III.
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(Table 4)

After we determined the presence of an association between lower incisor proclination and skeletal class III malocclusion severity, we performed linear regression analysis for IMPA, L1-GoMe, and L1-GoGn. The results of the linear regression analysis are shown in Table 5, Fig. 2, and Fig. 3.

Student's t-test showed no differences in dentoalveolar

Table 6. Student's *t*-test to compare variables between sexes

Change in	Sex	Mean	SD	*P*-value
U1-NA (°)	Male	14.9636	8.01291	0.812
	Female	14.4542	7.65591	
U1-NA (mm)	Male	4.6515	4.44579	0.280
	Female	3.4750	3.38285	
U1-Point A (mm)	Male	2.0697	3.03989	0.191
	Female	1.0083	2.89466	
U1-SN (°)	Male	17.1545	9.20998	0.601
	Female	15.8625	9.52228	
U1-PP (°)	Male	–13.6455	17.29659	0.102
	Female	–19.4542	8.30516	
U1-APog (mm)	Male	–1.2273	4.44503	0.483
	Female	–2.0042	3.63814	
U1-APog (º)	Male	0.0758	11.20321	0.892
	Female	–0.2792	8.10936	
L1-NB (°)	Male	0.7636	7.84824	0.754
	Female	1.3958	7.31339	
L1-NB (mm)	Male	–1.6515	3.01456	0.008*
	Female	0.2875	1.99244	
Tweed's IMPA (°)	Male	–8.0333	7.05588	0.870
	Female	–7.7250	7.43296	
L1-NPog (mm)	Male	–6.5818	3.69801	0.054
	Female	–4.8792	2.41192	
L1-APog line (mm)	Male	–8.7970	10.79776	0.492
	Female	–6.7167	11.73433	
L1-APog (mm)	Male	–8.1364	9.49493	0.742
	Female	–7.2542	10.60594	
L1-Mand plane (Go-Me) (°)	Male	–6.0333	7.05796	0.871
	Female	–5.7333	7.44029	
L1-GoGn (°)	Male	–6.0970	7.07153	0.851
	Female	–5.7542	7.31377	

(SD: standard deviation, IMPA: incisor mandibular plane angle)
*$P<0.05$.
Refer to Table 1 for the definition of landmarks.
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compensation of the maxillary incisors between males and females ($P>0.05$).(Table 6) However, comparison of lower incisors compensation between males and females revealed males had higher compensation of the lower incisors compared to females with regards to L1-NB (mm) ($P=0.008$).

IV. Discussion

Dentoalveolar compensation plays an important role in the exhibition of malocclusion as it masks the underlying severity of the skeletal malocclusion. There are several factors that play roles in dentoalveolar adaptation, such as a normal eruptive system without any systemic factors affecting the eruption pattern, forces exerted by the soft tissue envelope on the dental arches, swallowing patterns, non-nutritive habits, the influence of the neighboring teeth during eruption, and the inclined-plane effect of opposing teeth during occlusion and mastication[5]. Several studies have investigated dentoalveolar compensations, especially in class III malocclusions. Ishikawa et al.[9] performed a study in the Japanese female population to determine the cephalometric parameters that quantitatively describe dental compensations. However, in his study, the population did not solely represent class III malocclusion individuals as subjects with class I and class III malocclusions were included, as the cut-off ANB angle used in that study was 3.39°. We conducted this study to evaluate the quantum of dentoalveolar compensation in class III malocclusions in the Indian population, as ethnic origin and race contribute to the etiology of class III malocclusions. Different ethnicities may have different incisal compensations with different magnitudes of compensation. There are several cephalometric variables available to assess the axial inclinations of the upper and lower incisors, and not all parameters are equally correlated with prediction of the compensatory axial inclination of the incisors[9]. Hence, in our study, we evaluated eight dental parameters for upper and lower incisor position and inclination to see which parameter showed the strongest correlation with the jaw base for dentoalveolar compensation. We used the ANB angle to measure the skeletal base. ANB was chosen because it is the most common method of measuring the maxillomandibular differential[11] and also was considered to be the most valid cephalometric parameter in angle's class III subjects with counter-clockwise rotation and a flattened occlusal plane[12]. The current study was a self-

controlled study, in which the deviation in inclination of the incisors was calculated by subtraction from norm values. This way, we did not have to include a separate control group in which the inherent intra-arch abnormalities present could lead to a change in the axial inclination of the incisors regardless of the compensatory mechanism and thereby influence the results.

Interestingly, we found that the upper incisors compensated by proclination whereas the lower incisors were almost upright and showed no compensation. This indicates that the upper incisors responded more to the jaw discrepancy than the lower incisors. This is in accordance with the study by Kim et al.[7] who evaluated dentoalveolar compensation in skeletal class III malocclusions with both positive and negative overjets. They showed that the upper incisors were more flared in the positive overjet group than the negative overjet group, whereas no difference was found in lower incisor inclination. The authors suggested that this was because the position of the mandibular incisors is firmly regulated by the labiolingual muscular environment, so that incisal occlusion does not affect the position of incisors. In our study, the lower incisors were in fact more upright than retroclined. We came to this conclusion by comparison to normal values for all parameters obtained through literature review. However, the norms for axial inclination differ between various ethnic and racial groups[13]. This could have been one of the reasons why the lower incisors did not show significant compensation in our study.

In contrast to our findings, Al-Kadhim et al.[14] showed that dentoalveolar compensation in class III skeletal pattern was by retroclination of the lower incisors. These differences in findings could be due to the different ethnicities of our respective study populations.

Furthermore, correlation analysis to identify the influence of incisor compensation showed in that as class III severity increased, the upper incisors became less compensatory (as seen by U1-APog and incisal edge to N-Pog values). Additionally, the maxillary base did not affect upper incisor compensation. This is consistent with the findings of Alhammadi[15], namely that compensation is not affected by the holding jaw base. However, they found a moderate correlation between ANB and upper and lower incisor inclination. We attribute this discrepancy in results to the fact that their study evaluated the association between ANB and incisor inclination whereas we investigated the association between the magnitude of incisor compensation and severity of class III malocclusions. To the best of our knowledge, none of the studies performed to date have evaluated the correlation between the severity of class III skeletal malocclusions and the magnitude of incisor compensation.

Although the lower incisors were upright and did not retrocline in mild class III cases, as the class III malocclusion became more severe, the lower incisors began to compensate by retroclination as seen from the positive association between L1-GoMe, L1-GoGn, and IMPA. The magnitude of compensation revealed that as the ANB decreased by 1 degree from normal, IMPA and L1-GoMe decreased by 0.79° and L1-GoGn decreased by 0.81°.

Together, the results from our study and those of previous studies indicate that it is not always only anteroposterior relationships that influence dentoalveolar compensation, but also several other factors such as vertical growth pattern[15], transverse relationships, the inherent relationship of the jaw with the skull base[16], and the effects of oral musculature pressure, upper lip thickness, and lip height[17].

The limitations were (1) lack of cephalometric norms for specific ethnic populations to evaluate incisor inclination, (2) lack of equal sample sizes for retrognathic maxillae and prognathic mandibles, and (3) small sample size.

V. Conclusion

In class III skeletal malocclusions, the upper incisors contribute more to compensation by proclination than the lower incisors until a certain limit. However, as the severity of class III malocclusion increases, the upper incisors stop compensating and the lower incisors began to exhibit more compensation. For every degree of reduction in ANB angle, IMPA and L1-GoMe decreased by 0.79°, respectively, and L1-GoGn decreased by 0.81°. There was a difference in lower incisor compensation but not upper incisor compensation between males and females.

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Authors' Contributions

R.C. participated in data collection, study design, data anal-

ysis, writing of the manuscript. V.A. and V.K. participated in data analysis and writing of the manuscript. All authors read and approved the final manuscript.

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Ethics Approval and Consent to Participate

This study was approved by the Institutional Ethics Committee of Sri Ramachandra Institute of Higher Education and Research (SRIHER) (CSP/21/DEC/103/613). The written informed consent was waived due to the study's retrospective design.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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