

# The predictability of dentoskeletal factors for soft-tissue chin strain during lip closure

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**Objective:** To investigate the dentoskeletal factors which may predict soft-tissue chin strain during lip closure. **Methods:** The pretreatment frontal and lateral facial photographs and lateral cephalograms of 209 women (aged 18–30 years) with Angle's Class I or II malocclusion were examined. The subjects were categorized by three examiners into the no-strain and strain groups according to the soft-tissue chin tension or deformation during lip closure. Relationships of the cephalometric measurements with the group classification were analyzed by logistic regression analysis, and a classification and regression tree (CART) model was used to define the predictive variables for the group classification. **Results:** The lower the value of the overbite depth indicator (ODI) and the higher the values of upper incisor to Nasion-Pogonion (U1-NPog, mm), overjet, and upper incisor to upper lip (U1-upper lip, mm), the more likely was the subject to be classified into the strain group. The CART showed that U1-NPog was the most prominent predictor of soft-tissue chin strain (cut-off value of 14.2 mm), followed by overjet. **Conclusions:** To minimize strain of the soft-tissue chin, orthodontic treatment should be oriented toward increasing the ODI value while decreasing the U1-NPog, overjet, and U1 upper lip values.  
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## INTRODUCTION

The contour of the lower face, including the lips and soft-tissue chin, is thought to be closely related to the underlying dentoalveolar structure. Both the upper and the lower lips are known to increase in length during growth and maintain a fairly constant vertical relationship with the edges of the corresponding central incisors after their full eruption.<sup>1</sup> During lip closure, a subject with a normal maxillofacial skeletal pattern shows negligible contraction of the perioral musculature, and therefore, changes in the contour of the lip and soft-tissue chin are minimal.<sup>2,3</sup>

On the other hand, many orthodontic patients display visible tension in their soft-tissue chin during lip closure, which is often considered unesthetic. In particular, patients who have a long anterior vertical dimension or protruded incisors with a large interlabial gap show strain of their soft-tissue chin in an effort to close their lips, because the lower lip is elongated and the mentolabial sulcus moves upward and forward.<sup>2,4,5</sup>

One goal of orthodontic treatment is to achieve a desirable facial profile by obtaining not only satisfactory dental and skeletal relationships but also esthetic soft-tissue components including the lips and chin. Any dental or skeletal factors found to be contributing to either tension in or deformation of the soft-tissue chin must be considered during diagnosis and treatment planning for better outcomes. The influence of diagnostic factors on pretreatment or posttreatment variables can be evaluated through various analytical methods such as logistic and multivariate regression analyses.<sup>6,7</sup> However, these analyses often include complicated predictive equations, which occasionally present difficulties in result interpretation. A classification and regression tree (CART) is a useful analytical method that integrates the data of complex regression analyses and converts them into a simple tree model providing information on diagnostic factors in the order of their impact on the dependent variable with cut-off values.<sup>8,9</sup>

Studies using CART as a mean of analytical method for the evaluation of the soft-tissue chin are scarce. The purpose of this study was to investigate the dento-skeletal factors which may predict soft-tissue chin strain during lip closure. The potential predictive variables were evaluated by logistic regression analysis and a CART model.

## MATERIALS AND METHODS

Two hundred and ninety-three women with Angle's Class I or II molar relationships and aged 18 - 30 years were recruited from three private orthodontic clinics. The exclusion criteria were as follows: (1) previous ortho-

dontic treatment or orthognathic surgery; (2) multiple missing teeth; (3) presence of prostheses in edentulous areas; (4) ANB less than 0°; (5) anterior edge-to-edge bite or crossbite; and (6) congenital anomalies such as cleft lip and palate.

The subjects' pretreatment records dating from 2007 to 2010 were examined. The records included frontal and lateral facial photographs taken with the lips in the closed and relaxed positions and lateral cephalograms obtained with the teeth in centric occlusion. Three orthodontists (Y.K., J.P., and Y.Y.) visually inspected the lips, mentolabial sulcus, and soft-tissue chin of the subjects in these records and classified the subjects into either the no-strain or the strain group according to the soft-tissue chin tension or deformation during lip closure.

Cochran's Q test was performed to compare the proportion of subjects classified into the strain group by the three examiners: the differences were found to be significant ( $p = 0.02$ ). Further, McNemar's test was used to compare the proportion of subjects classified into the strain group between the examiners. Examiners Y.K. and Y.Y. showed no significant difference ( $p = 0.892$ ), with their concurrence being 81.5%. However, examiner J.P. showed significant discordance with both examiner Y.K. and examiner Y.Y. ( $p = 0.036$  and  $0.014$ , respectively). The results of these tests suggested that the examiners showed subjectivity in classifying the women into the no-strain or strain group; to enhance the credibility of this research, the data of only 209 subjects (114 and 95 women from the no-strain and strain groups, respectively) who had been unanimously classified by all the three examiners were used.

The lateral cephalogram of each subject was traced on standard 0.003 inch acetate tracing paper with a 0.3 mm mechanical pencil and measured on a scale with 0.5 mm and 0.5° intervals by one orthodontist. The description of cephalometric landmarks and references for the skeletal and dental measurements are shown in Table 1.

SPSS version 18.0 (IBM Inc., Armonk, NY, USA) was used for the data analyses. The reliability of the measurements was assessed via intraclass correlation coefficients (ICCs) and the Wilcoxon signed-rank test. A t-test was performed to compare the differences in the mean values of the variables between the groups. Three variables that did not pass the normality test were analyzed by the Mann-Whitney U-test. Multivariate analysis of variance (MANOVA) was conducted to determine the intergroup differences in the variables after age adjustment. The chi-square test was carried out to evaluate the significance of the group distribution according to Angle's classification of malocclusion. Moreover, logistic regression analysis was used to deter-

**Table 1.** Description of the landmarks and measurements used in this study

	Abbreviation	Definition
<b>Landmarks</b>		
Upper incisor point	U1	Tip of the crown of the upper incisor
Lower incisor point	L1	Tip of the crown of the lower incisor
Stomion Superius	Stm <sub>s</sub>	Most inferior point on the upper lip vermilion
<b>Measurements and reference planes</b>		
Frankfurt horizontal plane	FH	Plane formed by Porion and Orbitale
Palatal plane	PP	Plane formed by Anterior nasal spine and Posterior nasal spine
Occlusal plane	OP	Plane formed by two intersection points of upper and lower first molars and incisors
Mandibular plane	MP	Plane formed by Gonion and Menton
Wits appraisal		Distance between two points erected perpendicularly on functional occlusal plane (line drawn through the overlap of the mesiobuccal cusps of the first molars and the buccal cusps of the first premolars) from points A and B
Posterior facial height to Anterior facial height ratio	PFH/AFH	Value of Sella-to-Gonion length divided by Nasion-to-Menton length
Overbite depth indicator	ODI	AB plane to MP ± PP angle (FH-PP)
Anteroposterior dysplasia indicator	APDI	Facial angle (FH-NPog) ± AB plane angle (AB-NPog) ± PP angle
Incisor mandibular plane angle	IMPA	The angle formed by lower incisor axis and mandibular plane
Upper incisor to Nasion-Pogonion	U1-NPog	Perpendicular distance from upper incisor tip to Nasion-Pogonion
Upper incisor tip to upper lip	U1-upper lip	Perpendicular distance from upper incisor tip to Stm <sub>s</sub> , parallel to N-perpendicular line to FH

All landmarks and measurements are defined on the lateral cephalograms.

mine the possible discriminants for each group. Then, a CART model was constructed to obtain cut-off values for the variables selected as predictors. Tracing and measurement errors were determined by retracing 20 cephalograms acquired through systematic random sampling. The significance level was set at 0.05.

### RESULTS

The results of the Wilcoxon signed-rank test reflected no significant differences in the repeated measurements of all the variables ( $p > 0.05$ ; Table 2). The measurements were considered reliable and measurement errors were thought to be minimal because 26 of the 27 analyzed variables exhibited ICC values of 0.95 or higher ( $p < 0.001$ ; Table 2).

As shown in Table 3, the mean values of 22 of the 27 variables were significantly different between the groups. Meanwhile, the age differences between the groups were not significant ( $p = 0.362$ ). Further, in the MANOVA, the values of Wilks' lambda indicated that the intergroup differences in the mean values of the variables after age adjustment were comparable to those before age adjustment ( $p < 0.05$ ).

According to Angle's classification of malocclusion, 124 and 85 subjects had Class I and II malocclusions, respectively. The strain group included a lower number of subjects with Class I malocclusion (48 [38.7%] vs. 76 [61.3%]) and a slightly higher proportion of subjects with Class II malocclusion (47 [55.3%] vs. 38 [44.7%]) than the no-strain group. The chi-square test showed that this trend was significant ( $p = 0.018$ ).

The variables analyzed in the forward stepwise (likelihood ratio) logistic regression analysis included the cephalometric measurements, age, and Angle's classification of malocclusion (Class I or II malocclusion). Four variables were chosen as the most prominently related factors for the group classification in the final model (Table 4): overbite depth indicator (ODI), upper incisor to N-Pog plane (U1-NPog, mm), overjet, and upper incisor to upper lip (U1-upper lip, mm).

A logit model using the four selected variables was derived as follows:

$$S = \frac{\ln(\text{Pr}(\text{SG}))}{\text{Pr}(\text{NSG})} = 1.55 - 0.14A + 0.37B + 0.37C + 0.49D$$

where "A," "B," "C," and "D" are the coefficient values

**Table 2.** Results of the reliability and Wilcoxon signed-rank tests

		ICC		Wilcoxon test
		95% CI	<i>p</i> -value*	<i>p</i> -value
AB-GoMe (°)	1.000	0.999 - 1.000	< 0.001	0.109
Palatal plane angle (FH-PP, °)	0.995	0.988 - 0.998	< 0.001	0.453
Occlusal plane angle (FH-OP, °)	0.764	0.494 - 0.899	< 0.001	1.000
FH-GoMe (°)	0.999	0.998 - 1.000	< 0.001	0.375
SNA (°)	0.996	0.989 - 0.998	< 0.001	0.219
SNB (°)	0.983	0.957 - 0.993	< 0.001	0.188
ANB (°)	0.997	0.992 - 0.999	< 0.001	1.000
Facial convexity (NA-NPog, °)	0.996	0.990 - 0.998	< 0.001	0.781
Facial angle (FH-NPog, °)	0.993	0.982 - 0.997	< 0.001	1.000
Y-axis (FH-SGn, °)	0.995	0.988 - 0.998	< 0.001	1.000
Gonial angle (Ar-Go-Me, °)	0.990	0.976 - 0.996	< 0.001	0.459
Effective maxilla length (Co-A, mm)	0.998	0.994 - 0.999	< 0.001	0.688
Effective mandible length (Co-Gn, mm)	0.998	0.995 - 0.999	< 0.001	1.000
ANS-Me (mm)	0.998	0.995 - 0.999	< 0.001	1.000
ODI	0.998	0.995 - 0.999	< 0.001	1.000
APDI	0.999	0.997 - 0.999	< 0.001	1.000
Wits appraisal (mm)	0.998	0.996 - 0.999	< 0.001	1.000
PFH/AFH (SGo/NMe)	0.996	0.989 - 0.998	< 0.001	1.000
U1-FH (°)	0.999	0.997 - 0.999	< 0.001	0.289
L1-FH (°)	0.999	0.998 - 1.000	< 0.001	0.375
IMPA (°)	0.999	0.996 - 0.999	< 0.001	0.754
Interincisal angle (°)	0.997	0.992 - 0.999	< 0.001	0.750
U1-NPog (mm)	0.996	0.989 - 0.998	< 0.001	0.453
L1-NPog (mm)	0.994	0.986 - 0.998	< 0.001	1.000
Overjet (mm)	0.997	0.993 - 0.999	< 0.001	1.000
Overbite (mm)	0.999	0.997 - 1.000	< 0.001	1.000
U1-upper lip (mm)	0.983	0.958 - 0.993	< 0.001	0.219

\*Statistically significant (*p* < 0.05).

ICC, Interclass correlation coefficient; CI, confidence interval; A, A-point; B, B-point; Go, gonion; Me, menton; S, sella; N, nasion; Pog, pogonion; Gn, gnathion; Ar, articulare; Co, condylion; ANS, anterior nasal spine.

See Table 1 for the detailed description of the measurements.

of ODI, U1-NPog, overjet, and U1-upper lip, respectively (Table 4).

The logit model indicated that the lower the ODI value and the higher the U1-NPog, overjet, and U1-upper lip values, the greater was the probability of the subject being included in the strain group. By inverting the logit model with exponential function, the following equation was obtained:

$$\text{Pr(SG)} = \frac{\exp(S)}{1 + \exp(S)}$$

where “S” is the logit model and “Pr(SG)” is the probability of classification into the strain group.

The prediction rate at which the group classification by using the four selected variables would concord with the actual classification was 81.8% (Table 5).

The CART model constructed by using the four selected variables provided the cut-off values of these variables (Figure 1). The tree building began at the root (or parent) node (node 0), which included all the subjects in the dataset. The best splitter variable for each node was selected to maximize the average “purity” of

**Table 3.** Results of the t-test and Mann-Whitney U-test

	No-strain group	Strain group	p-value
AB-GoMe (°)	71.75 ± 0.46	70.08 ± 0.54	0.019*
Palatal plane angle (FH-PP, °)	2.32 ± 0.25	1.46 ± 0.31	0.031*
Occlusal plane angle (FH-OP, °)	10.64 ± 0.37	12.06 ± 0.36	0.006*
FH-GoMe (°)	27.24 ± 0.53	32.57 ± 0.60	< 0.001*
SNA (°)	81.82 ± 0.34	80.88 ± 0.33	0.052
SNB (°)	78.18 ± 0.35	75.68 ± 0.34	< 0.001*
ANB (°)	3.62 ± 0.21	5.18 ± 0.25	< 0.001*
Facial convexity (NA-NPog, °)	6.44 ± 0.48	10.12 ± 0.56	< 0.001*
Facial angle (FH-NPog, °)	86.88 ± 0.28	84.89 ± 0.27	< 0.001*
Y-axis (FH-SGn, °)	63.18 ± 0.31	66.11 ± 0.38	< 0.001*
Gonial angle (Ar-Go-Me, °)	119.96 ± 0.60	123.08 ± 0.65	0.001*
Effective maxilla length (Co-A, mm)	91.18 ± 0.42	90.12 ± 0.46	0.089
Effective mandible length (Co-Gn, mm)	120.79 ± 0.52	119.99 ± 0.58	0.308
ANS-Me (mm)	74.25 ± 0.48	78.23 ± 0.55	< 0.001*
ODI	74.1 ± 0.54	71.53 ± 0.65	0.003*
APDI	83.66 ± 0.45	79.27 ± 0.52	< 0.001*
Wits appraisal (mm)	-1.53 ± 0.25	0.24 ± 0.32	< 0.001*
PFH/AFH (SGo/NMe)	0.70 ± 0.01	0.65 ± 0.01	< 0.001*
U1-FH (°)	115.71 ± 0.65	117.76 ± 0.64	0.026*
L1-FH (°)	57.00 ± 0.70	51.23 ± 0.76	< 0.001*
IMPA (mm)	96.23 ± 0.74	96.65 ± 0.74	0.690
Interincisal angle (°)	121.18 ± 0.95	113.23 ± 0.96	< 0.001*
U1-NPog (mm)	10.97 ± 0.35	16.13 ± 0.40	< 0.001*
L1-NPog (mm)	7.69 ± 0.32	11.25 ± 0.36	< 0.001*
Overjet (mm)	2.89 ± 0.15	4.81 ± 0.28	< 0.001* <sup>†</sup>
Overbite (mm)	1.57 ± 0.16	1.31 ± 0.27	0.708 <sup>†</sup>
U1-upper lip (mm)	2.83 ± 0.15	4.07 ± 0.19	< 0.001* <sup>†</sup>

Values are presented as mean ± standard error.  
 \*Statistically significant ( $p < 0.05$ ); <sup>†</sup>Mann-Whitney U-test.  
 A, A-point; B, B-point; Go, gonion; Me, menton; S, sella; N, nasion; Pog, pogonion; Gn, gnathion; Ar, articulare; Co, condylion; ANS, anterior nasal spine.  
 See Table 1 for the detailed description of the measurements.

the two child nodes. The best splitter variable for node 0 was found to be U1-NPog, with a cut-off value of 14.2 mm. Therefore, in node 1, 80% of the subjects showing

a U1-NPog value less than or equal to 14.2 mm would be categorized into the no-strain group, and in node 2, 79.8% of the subjects showing a U1-NPog value greater than 14.2 mm would be categorized into the strain group. Accordingly, U1-NPog was considered the primary predictor, with the ability to classify approximately 80% of the total subjects into the strain or no-strain group at the value of 14.2 mm and without the necessity of the other variables. The next splitter variable for both node 1 and node 2 was considered to be overjet, although the number and condition of the subjects in these nodes were different (i.e., node 1 contained 120 subjects with a U1-NPog value  $\leq 14.2$  mm and node 2 comprised 89 subjects with a U1-NPog value  $> 14.2$  mm). The tree building continued until one of the coupled nodes showed 100% purity in the categorization of the groups, as seen in nodes 12, 14, and 15. The predictability of the group classification according to the CART model is shown in Table 6.

### DISCUSSION

During lip closure, the upper and lower lips cover two-thirds and one-third of the maxillary central incisors, respectively, and the main muscle activity is shown by the mentalis, followed by the lower and upper lips.<sup>1</sup> The mentalis is essential in both esthetic and functional aspects because it is responsible for the central motion of the lower lip and determining the position of the chin point.<sup>4,10</sup> Patients with the dolichofacial type or maxillary protrusion tend to overwork the mentalis and lower lip to compensate for the lip incompetence. This condition leads to tension in the soft tissue at the insertion point of the mentalis and dimpling at the soft-tissue chin point, which is considered functionally and esthetically unfavorable.<sup>2-4</sup>

In this study, frontal and lateral extraoral photographs taken with the lips in their resting and closed positions and lateral cephalograms obtained with the teeth in centric occlusion were examined. To eliminate discrepancies related to gender or age, the sample included only women. Further, only the subjects who were unanimously categorized into the no-strain or strain group by all the three examiners were included to allow the maximal objectivity.

To identify the cephalometric measurements highly related to strain of the soft-tissue chin, the CART method was applied. A CART is used in various dental and medical studies to evaluate diagnostic or predictive factors for a certain condition or disease.<sup>11-13</sup> This diagnostic tree is a machine-learning method that allows the construction of a prediction model from the data.<sup>8,9</sup> It exhibits independent variables (e.g., the cephalometric variables) in the order of their influence on



**Table 4.** Results of the logistic regression analysis

Variable	Coefficient	SE	Wald	p-value	OR	95% CI
ODI	-0.14	0.04	13.83	< 0.001	0.87	0.81 - 0.94
U1-NPog (mm)	0.37	0.07	32.63	< 0.001	1.45	1.28 - 1.65
Overjet (mm)	0.37	0.12	10.18	0.001	1.45	1.15 - 1.82
U1-upper lip (mm)	0.49	0.13	14.22	< 0.001	1.64	1.27 - 2.11
Constant	1.55	2.53	0.38	0.539	4.72	

SE, Standard error; OR, odds ratio; CI, confidence interval. See Table 1 for the detailed descriptions of the measurements.

**Table 5.** Group predictability of the variables derived from the logistic regression analysis

Observed	Predicted		Correct (%)
	No-strain group	Strain group	
Group			
No-strain group	98	16	86.0
Strain group	22	73	76.8
Overall (%)			81.8

the dependent variables (e.g., no-strain or strain group) in a stratified manner, with the earlier division or node (higher in the tree) demonstrating a greater effect. Its main advantage is that it defines the cut-off values for dividing the parent node into the two child nodes that can simplify the decision for one way or the other. Another advantage is the graphical presentation of the tree diagram, which effectively aids in the interpretation of complex statistical data. The child nodes can each be recursively divided into two nodes, forming additional child nodes with their own splitters and cut-off values. Of the four discriminants selected in this study, the CART model showed that U1-NPog had the highest differentiability at a cut-off value of 14.2 mm.

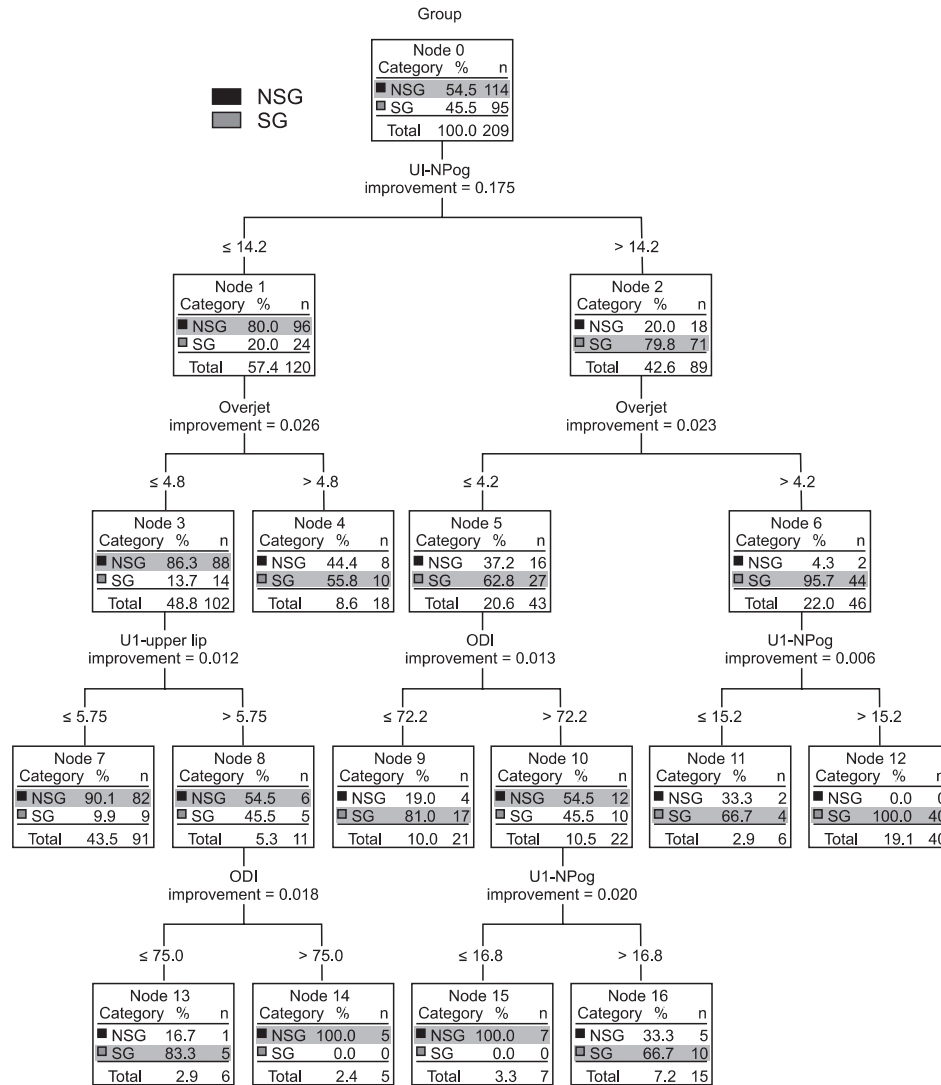
In a previous study, subjects with Class II division 1 malocclusion and lip incompetence had higher perioral muscle activities than those with normal occlusion.<sup>14</sup> Further, in both maxillary and bimaxillary protrusion cases, a greater amount of muscle tension developed from the lower lip to the chin in the closed lip position, because the amount of lower lip movement increased in relation to the degree of maxillary incisor protrusion.<sup>3</sup> These studies are highly comparable to the present study as they evaluated Asian male and female patients equivalently or female patients only. Accordingly, maxillary incisor protrusion has a notable effect on the lower lips and can lead to increased strain of the soft-tissue chin.

Moreover, the degree of the chin prominence relative to

the lip and maxillary incisors should not be overlooked. The chin provides a fundamental base on which the lips rely for support and the balance of the lip position heavily depends on the strength of the chin.<sup>15</sup> If the chin is too weak, the relative distance to the maxillary incisors would increase, which might cause the lower lip to protrude in order to reach the maxillary incisors during lip closure and lead to soft-tissue tension in the mentalis area. Therefore, the optimal treatment plan to relieve strain of the soft-tissue chin should include retraction of the maxillary incisors or orthognathic surgery such as bimaxillary anterior subapical osteotomy where a more prominent chin profile is preferred.<sup>5,16</sup>

The next predictive variable in the CART model was overjet, with cut-off values of 4.8 and 4.2 mm. Previous studies have shown the influence of the overjet on lip activity. An increased overjet was associated with decreased activity of the upper lip and increased activity of the lower lip; a positive correlation was noted between the overjet and the activity of the lower lip during lip closure, speech, and mastication.<sup>14</sup> Otuyemi<sup>17</sup> reported that in a preadolescent Nigerian population, an overjet greater than 6 mm was strongly related with a “trapped” lower lip and that greater than 7 mm led to inadequate coverage of the maxillary incisors by the lower lip. On the other hand, a direct correlation between the varying overjet and the different upper lip positions has not been shown, confirming a strong association between the overjet and the lower lip rather than with the upper lip.<sup>18</sup> Although these studies were performed with varying age groups and included male subjects, the results of the present study are in agreement with the previous findings concerning the influence of a large overjet on the movement of the lower lip. Therefore, acquiring a normal overjet may minimize malfunction of the lower lip and distortion of the mentalis.

U1-upper lip (mm) is a measurement reflecting the relative length of the lip. Its average values in the strain and no-strain groups were 4.07 and 2.83 mm, respectively, indicating that maxillary incisor extrusion coincides with increased strain in the mentalis. This relationship was significantly different in the subjects



**Figure 1.** Classification and regression tree (CART) model for defining the predictors (U1-NPog, overjet, U1-upper lip, and ODI) in the classification of the no-strain group (NSG) and strain group (SG). Refer to Table 1 for the description of the measurements.

**Table 6.** Predictability of the classification and regression tree (CART) model

Observed	Predicted		Correct (%)
	No-strain group	Strain group	
Group			
No-strain group	94	20	82.5
Strain group	9	86	90.5
Overall (%)			86.1

with Class II division 1 and Class I malocclusions, implying that the maxillary incisors tend to supra-erupt in Class II division 1 malocclusion.<sup>2</sup> Hayashida et al.<sup>19</sup>

reported that the most influential factor for the vertical position of the lower lip is the varying position of the tip of the maxillary incisor. An extruded maxillary incisor causes cushioning of the lower lip on the lingual surface and leads to eversion of the lower lip and distortion of the mentolabial sulcus and mentalis. Therefore, the vertical position of the maxillary incisors should also be considered together with the smile arc in the esthetic aspect of orthodontic treatment.<sup>2,20,21</sup>

The ODI was the only skeletal factor among the selected predictors and its influence was not as conspicuous as that of the other variables, which are related to the position of the maxillary incisors. Although its influence is limited, the treatment plan should be oriented toward increasing the ODI value to decrease

tension in the mentalis. However, this may be difficult to achieve because the AB plane angle should not be increased in treating Class I and II malocclusions. Therefore, prevention of extrusion or active intrusion of the maxillary molars is required to maintain or decrease the mandibular angle.

The chi-square test showed an apparent discrepancy in the sample distribution of Angle's classification of malocclusion between the groups ( $p = 0.018$ ). Although the measurements were not compared between skeletal Class I and skeletal Class II malocclusions, the differences in the cephalometric variables imply that the skeletal pattern between the groups was different, and the strain group showed a higher tendency for retrognathism, convex profile, and dolichofacial type.

Patients showing unfavorable strain at the soft-tissue chin may be managed by an orthodontic intervention – often involving retraction of anterior teeth – to establish satisfactory anterior dental relationship accordingly which induces changes in the lip posture, leading to lip closure without unnecessary tension in the lips and soft-tissue chin, and thus a more desirable profile is obtained.<sup>1</sup> Recognition of the variables predicting strain of the soft-tissue chin may enable the establishment of a guideline for the important dentoskeletal factors to be considered during diagnosis and treatment planning. To minimize strain of the soft-tissue chin, the treatment modality should be oriented toward decreasing the U1-NPog, overjet, and U1-upper lip values while increasing the ODI value.

Strain of the soft-tissue chin is influenced by not only the underlying dentoskeletal structures but also the thickness, length, and tone of the soft tissue.<sup>10</sup> Therefore, further studies should include soft-tissue variables to improve the predictability of the soft-tissue profile after orthodontic treatment. Given that the present study was limited to only Korean women, studies including men or various age or racial groups are warranted to compare the discrepancies arising from these predictive factors.

## CONCLUSION

1. ODI, U1-NPog, overjet, and U1-upper lip were found to be the discriminants for classifying the female adult subjects with Class I or II molar relationships into the no-strain or strain group, and the prediction rate of these variables for the group classification was 81.8%.
2. In the CART model, U1-NPog was the most predictive variable for categorizing the subjects into the no-strain or strain group, with a cut-off value of 14.2 mm.
3. The subjects in the strain group showed a retruded

mandible, vertical skeletal pattern, convex profile, and protruded dentoalveolar pattern compared with those in the no-strain group.

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