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Influence of Overjet Severity and Upper Incisor Impingement on the Lower Lip in Skeletal Class II Patients

Influencia de la Severidad del Resalte y el Pinzamiento del Incisivo Superior en el Labio Inferior en Pacientes Esqueléticos de Clase II

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SUMMARY: The objective of this study was to investigate the influence of overjet (OJ) severity and upper incisor impingement (UI-imp) on the lower lip (LL). One hundred and fifteen radiographs of skeletal Class II patients were grouped according to OJ severity: normal OJ (NOJ/n = 25), moderately excessive OJ (MEOJ/n = 45), and severely excessive OJ (SEOJ/n = 45). UI-imp was classified within subjects with excessive OJ (EOJ) according to the presence and absence of UI-imp on the LL: UI-imp (n = 50) and non-impingement (Non-imp) (n = 39). The skeletal, dental, and soft tissue characteristics were compared and analyzed for correlations. Prediction models were generated. Lower lip eversion (LLeversion), vermillion lower lip thickness (VLLT), and mentolabial sulcus depth (MSD) were significantly greater in SEOJ than NOJ. These LL variables worsened as OJ severity increased. OJ was significantly positively correlated to LLeversion and MSD and negatively correlated to upper lip strain (ULS), lip-chin-throat angle, and more backward LL position. Subjects with UI-imp exhibited similar OJ severity as the Non-imp group. The UI-imp group showed a significantly more backward sulcus inferior and deeper MSD. SNB, FMA, OJ, OB, UI, and LI contributed to the prediction models. Patients with SEOJ showed significantly greater LLeversion, VLLT, and MSD, while those with UI-imp showed increased MSD accompanied by a more backward sulcus inferior compared to those without. Improvement of lip morphology and lip-chin harmony may be expected upon EOJ and UI-imp reduction.

KEY WORDS: Lip; Incisor protrusion; Overjet; Malocclusion; Angle Class II.

INTRODUCTION

Excessive overjet (EOJ) is an unpleasant characteristic exhibited in dental Class II division 1 patients. It is a concern in orthodontic treatment since it involves both esthetics and function. An EOJ can be present in patients of all skeletal relationships when the cause is from dental origin; however, it usually exists in skeletal Class II patients and occurs in 20 - 30 % of the population (Ast *et al*., 1965; Cenzato *et al*., 2021) The teeth and the soft tissue appear unattractive (Santos & Ruellas, 2012) and are seen as a recognizable facial profile (Dimaggio *et al*., 2007).

Dental Class II patients with EOJ demonstrated a more prominent upper lip (UL) compared with Class I (Santos & Ruellas, 2012; Godt *et al*., 2013) and Class III groups (Godt *et al*., 2013) and a more prominent lower lip (LL) compared with the Class I group (Santos & Ruellas, 2012). However, the cause of the unappealing features has yet to be explored. Class II division 1 patients showed distinct UL, LL, and mentolabial angle characteristics (Haynes, 1975; Santos & Ruellas, 2012; Lee *et al*., 2015; Sarver, 2020). Eversion of the LL (LLeversion) against the maxillary incisors (UI) and incomplete lip seal were said to accompany EOJ. (Sarver, 2020) An OJ of >6 mm was related to LL trapping (Haynes, 1975). Also, when EOJ is caused by protrusive UIs, a protruded UL and an acute nasolabial angle (NLA) can be observed. A number of questions regarding the amount of OJ severity and whether the impingement of the UI (UI-imp) on the LL would impact the soft tissue remain to be addressed.

The lips and chin are two factors that impact the overall facial attractiveness in Class II patients (Parul *et al*., 2022). Knowledge of how OJ severity and UI-imp affect the LL and nearby soft tissue can lead to a more successful treatment plan. The existence of the relationship between these factors needs to be tested to further investigate the necessity of

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eliminating them as an integral part of the plan at the end of treatment. This study aimed to analyze and compare skeletal, dental, and soft tissue parameters in patients classified by OJ severity and the presence of UI-imp. We also aimed to find correlations and prediction models between the hard and soft tissue parameters and determine the association between OJ severity and UI-imp. The null hypothesis was that no significant differences could be detected in the soft tissue parameters of patients with different levels of OJ severity or the presence of UI-imp with no correlation among the hard and soft tissue parameters.

MATERIAL AND METHOD

The study protocol was approved by the ethics committee of the Faculty of Dentistry, Prince of Songkla University (EC6408-057). From a previous study of LL thickness (Lee *et al*., 2015), at least 112 subjects were required to detect a significant difference ($\alpha = 0.05$, $\beta = 0.2$) (G*Power, version 3.1). A total of 115 pre-treatment lateral cephalograms from 2013 to 2017 at the Faculty of Dentistry were included. The inclusion criteria were (1) skeletal Class II, (2) OJ ≥2 mm, (3) age 18 - 30 years with a cervical vertebral maturation (CVM) stage at least CS5 or CS6 (McNamara & Franchi, 2018), (4) no craniofacial deformities, and (5) no history of surgery in the head and neck area. The exclusion criteria were unclear landmarks and extensive restorations at the incisors.

Radiographs were categorized according to the OJ severity: normal OJ (NOJ) (2 - 4 mm), moderately EOJ (MEOJ) (> 4 - 6 mm), or severely EOJ (SEOJ) (> 6 mm) (Fig. 1). In MEOJ and SEOJ, the UI-imp was determined by observing the LL relationship to the UI from the radiographs modified from a study by Haynes (1975) (Fig. 2) and classified into UI-imp and Non-impingement (Non-imp) groups. Digitization and measurements using the Dolphin Imaging program version 11.9 (Patterson Dental Holdings, CA, USA) and ImageJ software (National Institutes of Health and the Laboratory for Optical and Computational Instrumentation; LOCI, University of Wisconsin, USA) were carried out by the primary investigator (KP) and calibrated by an expert orthodontist (CC). Illustrations of soft tissue landmarks according to Bravo *et al*. (Bravo *et al*., 1997) are

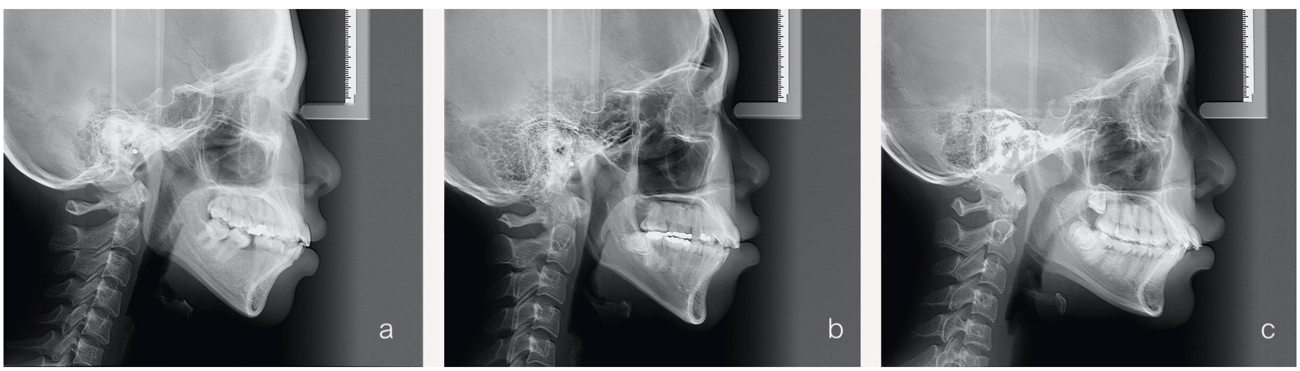

Fig. 1. Examples of lateral cephalometric radiographs show from left to right subjects with normal overjet (NOJ), moderately excessive overjet (MEOJ), and severely excessive overjet (SEOJ).

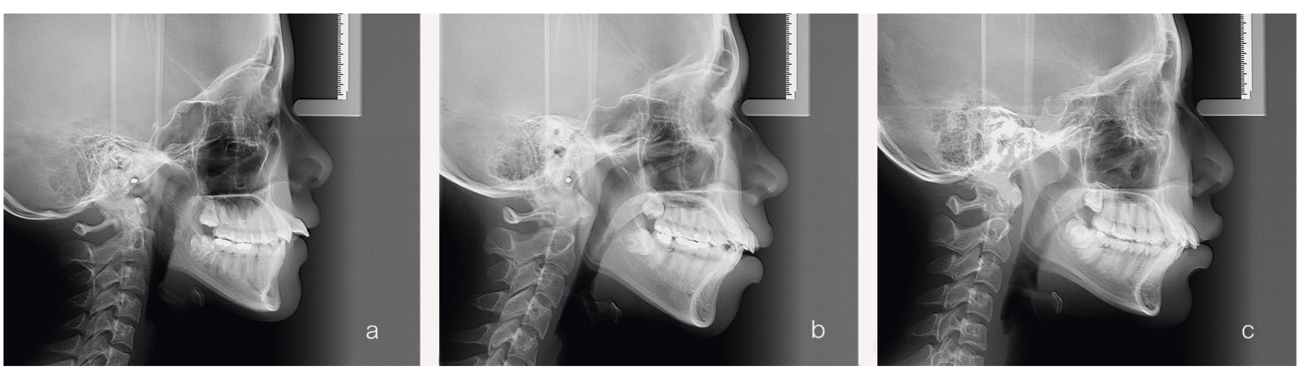

Fig. 2. Examples of positions -1, 0, and +1 modified from a study by Haynes (Haynes, 1975) (a) Position -1 (lower lip trapping): the upper border of the middle third of the lower lip (LL) is lingually positioned relative to the lingual surfaces of the maxillary central incisors (UI). (b) Position 0/Non-impingement (Non-imp): the upper border of the middle third of the LL is below the level of the incisal edges of the UI. (c) Position +1/Upper incisor impingement (UI-imp): the upper border of the middle third of the LL is related to the incisal thirds of the crowns of the UI.

shown in Figure 3. Lip thickness was measured according to a previous study (Lee *et al*., 2015). Upper lip strain (ULS) (Holdaway, 1983) was calculated by subtracting basic upper lip thickness (BULT) from vermilion upper lip thickness (VULT), where a negative value indicated the presence of ULS. LLeversion was calculated by subtracting basic lower lip thickness (BLLT) from vermilion lower lip thickness (VLLT), where a positive value indicated the presence of LLeversion. Parameters using true vertical plane (TVP) adapted from a previous study (Nuntasukkasame *et al*., 2012) were used to reflect the relationship in the natural head position.

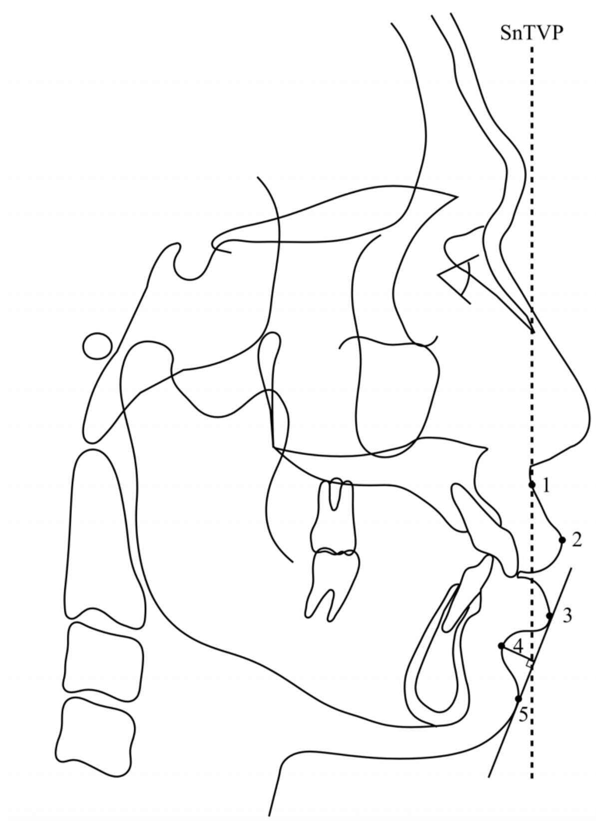

Fig. 3. Illustration of subnasale true vertical plane (SnTVP) and perioral soft tissue landmarks according to a study by Bravo *et al*. (Bravo *et al*., 1997). The landmarks are: 1. sulcus superior (Ss); 2. labrale superius (Ls); 3. labrale inferius (Li); 4. sulcus inferior (Si); and 5. soft tissue pogonion (Pg'). The distances from the landmarks perpendicular to the SnTVP were measured. The mentolabial sulcus depth was measured from a line perpendicular to point 4 from the plane formed by connecting point 3 to point 5.

Statistical analysis. The intraclass correlation coefficient (ICC) was determined by re-digitizing 30 random lateral cephalograms one month after the first measurement. Measurement error was determined using Dahlberg's formula (Dalhberg, 1940). Kolmogorov-Smirnov and Shapiro-Wilk normality tests were performed, and parametric tests were chosen. The classic analysis of variance (ANOVA) and Welch's ANOVA tests with Tamhane's T2 post hoc test were selected for multiple comparisons among the groups with different OJ severity. An independent t-test was used to compare parameters between sexes and the presence of UI-imp. Pearson correlations and multiple linear regressions were used to examine the relationships between soft tissue parameters and their potential hard tissue predictors. To prevent multicollinearity, only one parameter representing the UI and LI inclination and position with the highest degree of correlation with each dependent soft tissue parameter was chosen for the analysis of prediction models. Pearson's chi-square test was used to find an association between OJ severity and the UI-imp. Statistical analyses were conducted using SPSS (version 26). The level of significance was set at $P < 0.05$.

RESULTS

The average ICC of all variables was 0.92 (range 0.88 - 0.98), which indicated good reliability. Dahlberg's errors for linear and angular measurements were 0.3 mm and 1.4°, respectively. The effect size calculated from the VLLT was 0.36. Table I summarizes the demographic data of the subjects. No significant differences in any of the parameters and interaction effects were detected regarding the sex and age of the subjects included. Pearson's chi-square test demonstrated no association between OJ severity and the presence of UI-imp ($P = 0.112$).

Assessment of OJ severity revealed that Li-SnTVP and lip-chin-throat angle (LCTA) were significantly less in SEOJ compared with NOJ. Meanwhile, the mentolabial sulcus depth (MSD) and VLLT were significantly greater in SEOJ compared with NOJ. Si-SnTVP and VULT were significantly less when SEOJ was compared with MEOJ. None of the skeletal parameters among the groups were

Table I. Demographic data of normal overjet (NOJ), moderately excessive overjet (MEOJ), severely excessive overjet (SEOJ), lower lip trapping, upper incisor impingement (UI-imp), and non-impingement (Non-imp) groups.

Subject's	NOJ	MEOJ	SEOJ	Total	Lower lip trapping	Non-imp	UI-imp	Total
n (%)	25 (21.7%)	45 (39.1%)	45 (39.1%)	115	1 (1.1%)	39 (43.3%)	50 (55.7%)	90
Mean age ± SD	23.16 ± 3.13	22.88 ± 4.31	22.45 ± 3.10	23.04 ± 3.41	NA	24.50 ± 3.65	22.11 ± 3.46	NA
Female sex	22	34	38	94 (81.7%)	1	32	39	72
Male sex	3	11	7	21 (18.3%)	0	7	11	18

significantly different, except Wits appraisal in which NOJ was significantly lower than SEOJ. The dental parameters, including OJ, OB, LI-SnTVP (deg and mm), LI-NB (deg), incisal-show-at-rest (ISR), were significantly different pairwise (Table II).

Table II. Comparison of lateral cephalometric mean ± standard deviation of skeletal, dental, and soft tissue parameters among normal overjet (NOJ), moderately excessive overjet (MEOJ), and severely excessive overjet (SEOJ) groups.

	NOJ (n = 25)	MEOJ (n = 45)	SEOJ (n = 45)	*P*-values NOJ/MEOJ	NOJ/SEOJ	MEOJ/SEOJ
Skeletal parameter						
SNA (deg)	85.76 ± 2.43	84.79 ± 3.32	84.75 ± 3.32	NS	NS	NS
SNB (deg)	79.52 ± 2.45	78.67 ± 3.47	77.85 ± 3.12	NS	NS	NS
ANB (deg)	6.24 ± 1.64	6.12 ± 1.80	6.91 ± 1.56	NS	NS	NS
Wits appraisal (mm)	7.86 ± 2.49	8.61 ± 2.59	9.76 ± 2.42	NS	*	NS
FMA (deg)	29.16 ± 4.81	26.94 ± 5.73	26.51 ± 5.74	NS	NS	NS
Dental parameter						
OJ (mm)	2.80 ± 0.67	5.22 ± 0.84	8.38 ± 1.38	*	*	*
OB (mm)	2.09 ± 1.00	3.32 ± 1.36	3.70 ± 1.84	*	*	NS
UI-NA (deg)	26.88 ± 5.70	26.80 ± 7.96	30.76 ± 7.77	NS	NS	NS
UI-NA (mm)	7.38 ± 2.43	6.80 ± 3.16	7.96 ± 2.84	NS	NS	NS
LI-NB (deg)	39.06 ± 4.61	35.94 ± 5.57	33.72 ± 6.82	*	**	NS
LI-NB (mm)	12.10 ± 2.15	10.00 ± 2.34	9.26 ± 2.62	**	**	NS
Interincisal angle (deg)	108.51 ± 7.54	111.83 ± 9.73	108.83 ± 7.70	NS	NS	NS
UI-SnTVP (deg)	30.72 ± 4.63	29.38 ± 6.10	33.62 ± 7.54	NS	NS	*
UI-SnTVP (mm)	-4.18 ± 2.41	-4.21 ± 1.73	-3.14 ± 2.95	NS	NS	NS
LI- SnTVP (deg)	43.14 ± 6.25	40.00 ± 6.92	38.64 ± 7.20	NS	*	NS
LI-SnTVP (mm)	-7.72 ± 2.87	-9.53 ± 1.89	-10.81 ± 3.35	*	*	NS
Incisal show at rest (mm)	3.42 ± 1.58	3.56 ± 1.66	2.60 ± 1.99	NS	NS	*
Soft tissue parameter						
FCA (deg)	13.55 ± 4.88	14.32 ± 5.37	15.87 ± 4.73	NS	NS	NS
NLA (deg)	89.83 ± 10.88	91.05 ± 11.27	91.39 ± 12.74	NS	NS	NS
NLA-HP (deg)	68.10 ± 9.95	68.92 ± 9.39	66.75 ± 11.26	NS	NS	NS
LCTA (deg)	122.00 ± 5.56	118.01 ± 5.92	115.87 ± 6.85	*	**	NS
Upper lip length (mm)	22.86 ± 2.62	22.39 ± 2.98	21.58 ± 2.60	NS	NS	NS
Interlabial gap (mm)	3.66 ± 1.96	3.11 ± 2.66	3.73 ± 2.72	NS	NS	NS
Vermillion upper lip thickness (mm)	11.28 ± 1.62	11.79 ± 2.18	10.80 ± 1.64	NS	NS	*
Basic upper lip thickness (mm)	12.36 ± 1.58	12.26 ± 1.83	12.08 ± 1.73	NS	NS	NS
Upper lip strain (mm)	-1.08 ± 1.53	-0.47 ± 2.02	-1.28 ± 1.74	NS	NS	NS
Vermillion lower lip thickness (mm)	13.92 ± 1.96	14.82 ± 2.37	15.51 ± 2.06	NS	**	NS
Basic lower lip thickness (mm)	11.04 ± 1.43	11.16 ± 1.79	10.88 ± 1.47	NS	NS	NS
Lower lip eversion (mm)	2.88 ± 2.13	3.67 ± 1.95	4.63 ± 1.93	NS	**	NS
Ss-SnTVP (mm)	0.00 ± 0.68	0.27 ± 0.70	0.34 ± 0.80	NS	NS	NS
Ls-SnTVP (mm)	6.68 ± 1.59	6.12 ± 1.63	6.28 ± 1.99	NS	NS	NS
Li-SnTVP (mm)	3.18 ± 3.06	2.11 ± 2.30	0.68 ± 3.21	NS	**	NS
Si-SnTVP (mm)	-8.60 ± 3.74	-8.66 ± 2.72	-10.29 ± 3.36	NS	NS	*
Pg'-SnTVP (mm)	-9.44 ± 4.17	-8.32 ± 3.29	-9.18 ± 3.83	NS	NS	NS
Mentolabial sulcus depth (mm)	-5.48 ± 1.39	-5.90 ± 1.15	-6.53 ± 1.44	NS	*	NS

*P < 0.05, **P < 0.01; NS, not significant; OJ, overjet; OB, overbite; UI, upper incisor; LI, lower incisor; SnTVP, subnasale true vertical plane; FCA, facial contour angle; NLA, nasolabial angle; LCTA, lip-chin-throat angle; Ss, sulcus superior; Ls, labrale superius; Li, labrale inferius; Si, sulcus inferior; Pg', soft tissue pogonion.

A significantly greater ANB and larger interlabial gap were observed in the Non-imp group compared with the UI-imp group. A significantly more backward Si-SnTVP, deeper MSD, and greater OB and ISR were observed in the UI-imp group compared with the Non-imp group (Table III).

Table III. Comparison of lateral cephalometric mean ± standard deviation of skeletal, dental, and soft tissue parameters between the non-impingement (Non-imp) and upper incisor impingement (UI-imp) groups.

Parameters	Non-imp (n = 39)	UI-imp (n = 50)	*P*-value
Skeletal parameter			
SNA (deg)	85.39 ± 3.60	84.41 ± 2.94	NS
SNB (deg)	78.46 ± 3.76	78.21 ± 2.87	NS
ANB (deg)	6.93 ± 1.49	6.20 ± 1.84	*
FMA (deg)	27.29 ± 6.15	26.24 ± 5.40	NS
Dental parameter			
OJ (mm)	6.84 ± 1.91	6.65 ± 1.83	NS
OB (mm)	3.11 ± 1.84	3.87 ± 1.31	*
UI-NA (deg)	27.28 ± 7.50	29.66 ± 8.23	NS
UI-NA (mm)	6.88 ± 2.95	7.75 ± 3.11	NS
LI-NB (deg)	35.22 ± 5.87	34.90 ± 6.16	NS
LI-NB (mm)	9.82 ± 2.30	9.61 ± 2.53	NS
UI-SnTVP (deg)	30.17 ± 6.97	32.15 ± 6.74	NS
UI-SnTVP (mm)	-3.40 ± 2.69	-3.95 ± 2.26	NS
LI- SnTVP (deg)	39.16 ± 7.24	39.87 ± 6.34	NS
LI-SnTVP (mm)	-10.30 ± 2.67	-10.24 ± 2.67	NS
Interincisal angle (deg)	110.56 ± 8.68	110.09 ± 9.21	NS
Incisal show at rest (mm)	2.56 ± 1.92	3.48 ± 1.79	**
Soft tissue parameter			
FCA (deg)	15.20 ± 4.63	15.08 ± 5.50	NS
NLA (deg)	89.21 ± 11.57	92.77 ± 12.27	NS
NLA-HP (deg)	66.46 ± 9.98	68.97 ± 10.72	NS
LCTA (deg)	115.96 ± 6.29	117.94 ± 6.35	NS
Upper lip length (mm)	22.39 ± 2.84	21.75±2.75	NS
Interlabial gap (mm)	4.87 ± 2.77	2.24 ± 1.99	**
Vermillion upper lip thickness (mm)	11.42 ± 2.21	11.24 ± 1.80	NS
Basic upper lip thickness (mm)	11.83 ± 1.57	12.41 ± 1.90	NS
Upper lip strain (mm)	-0.41 ± 1.85	-1.17 ± 1.89	NS
Vermillion lower lip thickness (mm)	15.40 ± 2.43	15.05 ± 2.05	NS
Basic lower lip thickness (mm)	11.03 ± 1.44	11.05 ± 1.78	NS
Lower lip eversion (mm)	4.37 ± 2.31	4.00 ± 1.72	NS
Ss-SnTVP (mm)	0.35 ± 0.76	0.26 ± 0.74	NS
Ls-SnTVP (mm)	6.64 ± 1.75	5.89 ± 1.82	NS
Li-SnTVP (mm)	0.89 ± 3.00	1.86 ± 2.71	NS
Si-SnTVP (mm)	-8.80 ± 2.66	-10.42 ± 3.50	**
Pg'-SnTVP (mm)	-9.10 ± 4.09	-8.55 ± 3.14	NS
Mentolabial sulcus depth (mm)	-5.98 ± 1.12	-6.58 ± 1.48	*

*P < 0.05, **P < 0.01; NS, not significant; OJ, overjet; OB, overbite; UI, upper incisor; LI, lower incisor; SnTVP, subnasale true vertical plane; FCA, facial contour angle; NLA, nasolabial angle; LCTA, lip-chin-throat angle; Ss, sulcus superior; Ls, labrale superius; Li, labrale inferius; Si, sulcus inferior; Pg', soft tissue pogonion.

From our results, UI-imp did not increase LL protrusion but contributed to increasing the MSD and a more backward sulcus inferius that was possibly due to a deeper OB and greater ISR that presented in this group. The UL and LL antero-posterior positions and thicknesses were similar with or without UI-imp. The Non-imp group, which presented incomplete lip seal (Proffit *et al*., 2019), had significantly larger ANB angles and interlabial gaps. The significant differences might be due to the hypo-function of the mentalis muscle. When the lips are apart at rest, the mentalis muscle showed lower electromyographic activity in the incomplete lip seal group compared with the complete lip seal group From

Table IV shows the correlations among the hard and soft tissue parameters. SNB, FMA, OJ, OB, UI-NA (mm), UI-SnTVP (deg and mm), LI-NB (deg and mm), and LI-SnTVP (deg and mm) contributed to the models in the stepwise multiple linear regression analysis. Each model could explain from 12.4 % to 52.4 % of the variance in the soft tissue variables. The UI position was used to predict all UL parameters with the exception of ULS, which was predicted by UI inclination. The LL parameters were mostly predicted by the LI position and inclination. Additionally, the UI position influenced the prediction of BLLT and LCTA. OJ and OB contributed to predicting VLLT, and OB contributed to predicting LLeversion (Table V).

DISCUSSION

Only skeletal Class II patients were included to limit factors caused by different skeletal discrepancies that might interfere with the appearance of the lips. Most subjects in our study were female; however, no differences were detected in any parameters regarding sex. The age and CVM stages were set to confine the subjects to non-growing subjects only.

The influence of OJ severity on the lips was demonstrated. A significant correlation was found between OJ and the appearance of UL and LL (ULS, VLLT, LLeversion, and MSD). Furthermore, OJ was also included in a prediction model of VLLT. To further elaborate this, the SEOJ showed significantly less protruded LL while having a significantly greater VLLT, LLeversion, and MSD than the NOJ group. As OJ increased, the VLLT got thicker and the MSD got deeper, although the Li-SnTVP and Si-SnTVP, which represent the antero-posterior position of the LL and mentolabial sulcus, respectively, were more

Table IV. Pearson correlation coefficients between hard and soft tissue variables.

	Soft tissue variable	Hard tissue variables														
		SNA (deg)	SNB (deg)	ANB (deg)	Wits (mm)	FMA (deg)	OJ (mm)	OB (mm)	UI-NA (deg)	UI-NA (mm)	UI-SnTVP (deg)	UI-SnTVP (mm)	LI-NB (deg)	LI-NB (mm)	LI-SnTVP (deg)	LI-SnTVP (mm)
Upper lip area	Vermillion upper lip thickness (mm)	-0.03	0.02	-0.10	0.01	-0.01	-0.19*	0.17	-0.23*	-0.17	-0.23*	-0.41**	0.05	0.02	-0.06	-0.24*
	Basic upper lip thickness (mm)	-0.11	-0.16	-0.18	0.01	0.09	0.01	0.15	0.13	0.18*	-0.00	-0.40**	0.09	0.13	0.09	0.30**
	Upper lip strain (mm)	0.07	0.04	0.06	0.00	-0.10	-0.20*	0.03	-0.36**	-0.35**	-0.24*	-0.05	-0.03	-0.11	-0.15	0.04
	Ss-SnTVP (mm)	-0.00	-0.00	0.01	-0.04	-0.27**	0.15	0.06	0.03	-0.03	0.12	0.33**	-0.09	-0.15	-0.12	0.19*
	Ls-SnTVP (mm)	0.27**	0.30**	-0.06	-0.16	-0.06	-0.07	-0.01	0.06	0.21*	0.28*	0.53**	0.16	0.29**	-0.01	0.46**
Lower lip area	Vermillion lower lip thickness (mm)	0.04	0.11	-0.10	0.06	-0.05	0.33**	0.34**	0.06	0.18	-0.06	-0.06	-0.20*	-0.07	-0.10	-0.30**
	Basic lower lip thickness (mm)	0.01	0.10	-0.18	-0.04	0.20*	-0.00	0.07	0.03	0.20*	-0.04	0.15	0.20*	0.22*	0.07	0.12
	Lower lip eversion (mm)	0.03	0.04	-0.02	0.09	-0.20*	0.35**	0.31**	0.05	0.05	-0.04	-0.18	-0.36**	-0.24*	-0.16	-0.41**
	Li-SnTVP (mm)	0.16	0.30**	-0.26**	-0.42**	-0.09	-0.33**	-0.07	0.04	0.19	0.22*	0.49**	0.03	0.21*	0.12	0.60**
	Si-SnTVP (mm)	0.19*	0.31**	-0.23*	-0.43**	-0.18	-0.20*	-0.03	0.05	0.02	0.26**	0.47**	-0.15	-0.12	-0.32**	0.56**
Chin area	Pg'-SnTVP (mm)	0.13	0.23*	_0.18	-0.37**	-0.29**	-0.02	0.05	0.00	-0.11	0.27**	0.47**	-0.29**	-0.34**	-0.50**	0.42**
	LCTA (deg)	0.04	0.04	0.02	0.02	0.23**	-0.30**	-0.05	-0.06	0.24*	-0.22*	-0.09	0.45**	0.53**	0.54**	0.11
	Mentolabial sulcus depth (mm)	0.034	0.037	-0.01	-0.16	0.03	0.30**	0.15	0.03	-0.01	0.15	0.12	0.13	0.13	0.02	0.40**

*P <0.05, **P <0.01; OJ, overjet; OB, overbite; UI, upper incisor; LI, lower incisor; SnTVP, subnasale true vertical plane; Ss, sulcus superior; Ls, labrale superius; Li, labrale inferius; Si, sulcus inferior; Pg', soft tissue pogonion; LCTA, lip-chin-throat angle.

Table V. Multiple linear regression between hard and perioral soft tissue variables.

Area	Dependent variable	Adjusted R^2	Independent variable	Unstandardized Coefficients B	Unstandardized Coefficients SE	Standardized Coefficients Beta	t	*P*-value
Upper lip area	Vermillion upper lip thickness (mm)	0.163	(Constant)	10.078	0.300	-	33.625	0.000
			UI-SnTVP (mm)	-0.320	0.067	-0.413	-4.815	0.000
	Basic upper lip thickness (mm)	0.154	(Constant)	11.135	0.274	-	40.683	0.000
			UI-SnTVP (mm)	-0.283	0.061	-0.402	-4.664	0.000
	Upper lip strain (mm)	0.124	(Constant)	1.560	0.619	-	2.520	0.013
			UI-NA (deg)	-0.087	0.021	-0.363	-4.144	0.000
	Ss-SnTVP (mm)	0.152	(Constant)	1.460	0.325	-	4.492	0.000
			UI-SnTVP (mm)	0.094	0.026	0.311	3.588	0.000
			FMA	-0.032	0.011	-0.241	-2.781	0.006
	Ls-SnTVP (mm)	0.276	(Constant)	7.760	0.260	-	29.895	0.000
			UI-SnTVP (mm)	0.384	0.058	0.531	6.669	0.000
Lower lip area	Vermillion lower lip thickness (mm)	0.148	(Constant)	12.842	0.559	-	22.313	0.000
			OB	0.354	0.127	0.257	2.782	0.006
			OJ	0.216	0.085	0.234	2.529	0.013
	Basic lower lip thickness (mm)	0.057	(Constant)	8.568	0.900	-	9.524	0.000
			LI-NB (mm)	0.048	0.023	0.187	2.056	0.042
			UI-NA (mm)	0.100	0.050	0.184	2.015	0.046
	Lower lip eversion (mm)	0.255	(Constant)	4.292	1.304	-	3.293	0.001
			LI-SnTVP(mm)	-0.207	0.061	-0.295	-3.428	0.001
			LI-NB (deg)	-0.089	0.028	-0.265	-3.162	0.002
			OB	0.238	0.109	0.185	2.180	0.031
	Li-SnTVP (mm)	0.410	(Constant)	-11.182	5.465	-	-2.046	0.043
			LI-SnTVP (mm)	0.580	0.073	0.575	7.952	0.000
			SNB	0.236	0.068	0.251	3.468	0.001
	Si-SnTVP (mm)	0.524	(Constant)	17.363	5.541	-	-3.134	0.002
			LI-SnTVP (mm)	0.646	0.073	0.582	8.912	0.000
			LI-SnTVP (deg)	-0.185	0.030	-0.396	-6.082	0.000
			SNB	0.277	0.067	0.267	4.116	0.000
Chin area	Pg'-SnTVP (mm)	0.518	(Constant)	11.838	1.938	-	6.108	0.000
			LI-SnTVP (deg)	-0.272	0.035	-0.517	-7.719	0.000
			LI-SnTVP (mm)	0.625	0.082	0.500	7.629	0.000
			FMA	-0.139	0.044	-0.210	-3.154	0.002
	LCTA (deg)	0.399	(Constant)	106.526	4.030	-	26.431	0.000
			LI-SnTVP (deg)	0.238	0.091	0.254	2.603	0.011
			LI-NB (mm)	0.716	0.247	0.285	2.904	0.004
			UI-SnTVP (deg)	-0.308	0.088	-0.312	-3.503	0.001
			UI-NA (mm)	0.588	0.208	0.260	2.831	0.006
	Mentolabial sulcus depth (mm)	0.147	(Constant)	-4.300	0.404	-	-10.641	0.000
			LI-SnTVP(mm)	0.182	0.040	0.393	4.542	0.000

UI, upper incisor; SnTVP, subnasale true vertical plane; Ss, sulcus superior; Ls, labrale superius; LI, lower incisor; OB, overbite; OJ, overjet; Li, labrale inferius; Si, sulcus inferior; Pg', soft tissue pogonion; LCTA, lip-chin-throat angle.

retruded. This finding showed that OJ severity played a part in the LLeversion and deepening of the MSD, which added more information to the results previously reported (Lee *et al*., 2015). However, a significant difference was observed only between the NOJ and SEOJ groups when the mean OJ difference was 5.58 mm.

On a side note, a more severe OJ was observed in patients with a more retrognathic mandible, maxillo-mandibular discrepancy, and lower FMA. Since insufficient dentoalveolar compensation can cause malocclusion, (Solow, 1980) EOJ could result from incisors with inadequate compensation. The UIs were similar while the LIs were significantly more retroclined and retruded in MEOJ and SEOJ than in NOJ. In our study population, we found that the cause of EOJ was mostly from the LIs. The effect of OJ severity on dentoalveolar compensation was previously studied. The maxillary anterior and basal dentoalveolar height was greatest in the group with EOJ acting as compensation. This pattern was not observed in the mandibular anterior and basal dentoalveolar height, which caused the LIs to adapt more because dentoalveolar compensation was less in the mandible than in the maxilla (Ceylan *et al*., 2003).

From our results, UI-imp did not increase LL protrusion but contributed to increasing the MSD and a more backward sulcus inferius that was possibly due to a deeper OB and greater ISR that presented in this group. The UL and LL antero-posterior positions and thicknesses were similar with or without UI-imp. The Non-imp group, which presented incomplete lip seal (Proffit *et al.*, 2019), had significantly larger ANB angles and interlabial gaps. The significant differences might be due to the hypo-function of the mentalis muscle. When the lips are apart at rest, the mentalis muscle showed lower electromyographic activity in the incomplete lip seal group compared with the complete lip seal group (Yamaguchi *et al.*, 2000). The greater skeletal discrepancy in Non-imp may be why the UI did not touch the LL. Only one study explored OJ and the relationships between the UI and the LL in children; however, the skeletal characteristics were not reported (Haynes, 1975).

Only 3 out of 5 LL positions (Haynes, 1975) were observed in 90 patients with EOJ, which were positions 1 (LL trapping), 0 (Non-imp), and +1 (UI-imp). Haynes reported that an OJ >6 mm was associated with a trapped LL, while the effect was not observed in groups with OJ of ≤ 6 mm (Haynes, 1975). Only one subject in our study had LL trapping (12.70 mm), which made a comparison with other groups impossible. More samples with LL trapping may help identify this association. We also noticed that OJ tended to decrease as LL coverage increased to the UI, while we detected no significant difference in the mean OJ values between the UI-imp and Non-imp groups. An OJ of > 6 was distributed across both groups, which we also found had no significant association between OJ and the presence of UI-imp. The difference could be because most Haynes's subjects had normal OJ, while almost 80% of our subjects had EOJ.

The lip thickness values (BULT, BLLT, VULT, and VLLT) in our subjects were close to a skeletal Class II division 1 in a Korean population (Lee *et al*., 2015) but not in a Chinese population (Guan *et al*., 2019), which reported a much greater BULT. The variance was due to the normal occlusion of their samples, which we assumed had average lip thickness. Our subjects had Class II malocclusion with proclined and protruded UIs that led to the thinner VULT.

Most prediction models included the UI and LI with the addition of OJ and OB when considering the LL. Predictions of soft tissue parameters of the mandible included skeletal divergence and the mandibular position. The models showed that all of these factors influenced the disposition of the perioral soft tissue. The mandibular soft tissues were mainly influenced by the LI; however, the BLLT and LCTA were equally affected by LI and UI as shown by the standardized coefficients. This finding confirms the impact that the UIs possibly have on the LL. Nevertheless, the VLLT and LLeversion were not correlated to any of the UI parameters. A previous study reported a significantly more LLeversion in Class II division 1 than Class I subjects caused by the position of the UI. Although the UI position value was unfortunately not reported, a significant value in UI inclination (1-SN angle) between the groups was reported (Santos & Ruellas, 2012). The inconsistency with our results could be from many factors since only limited parameters were reported in that study. Using the SN plane might alter incisor inclination because intracranial landmarks are affected by biological variation (Bjork, 1951; Bjehin, 1957). All radiographs taken in our institute were in the natural head position, which represented the "true life appearance" of the subjects. (Lundström & Lundström, 1992) Extracranial reference lines, such as TVP, have been proposed to avoid the problems with intracranial variations (Athanasiou, 1995). Many dental parameters with TVP in our study were correlated with soft tissue variables and played roles in their prediction models (Table V).

In conventional orthodontic treatment, corrections of the inclination and position of the UI and LI, as well as the OJ and OB, should improve lip and chin esthetics. As clinicians, we aim to create an ideal OJ at the end of treatment. In some situations where it might be harder to achieve an optimum result, this study is a reminder of the importance of eliminating EOJ. It is important to evaluate the presence of the remaining OJ at the final stage of treatment since our results showed that a greater OJ led to a greater impact on the LL and chin appearance. In addition to incisal show, the planned vertical position of the UI should consider the state of their impingement on the LL. However, procumbence of the perioral soft tissue might remain with incomplete correction of these factors. Patients need to be informed of the possibility of persistent procumbence after treatment since many factors play a role in soft tissue appearance. Nevertheless, post-treatment data should be studied further to confirm the effects.

The limitation of this study lies within the nature of a retrospective study. The evaluation of UI-imp could only be determined in the static state from the radiographic images of lip posture. Furthermore, oral habits could only be reviewed through the treatment history archine, and muscle function that included lip and mentalis strain could not be accurately determined. Even though we controlled the age and growth status of the samples, other confounding factors might have influenced the lip appearance. The generalizability of this work may be limited to Asian patients since ethnicity also influences lip morphology (Wong *et al*., 2010; Vela *et al*., 2011). Since only non-growing patients were included, the results cannot be applied to growing patients.

CONCLUSIONS

The SEOJ group (>6 mm) showed a significantly more everted and retruded LL, deeper MSD, and smaller LCTA than patients with NOJ. Meanwhile, the MEOJ group (4–6 mm) had only a significantly less LCTA compared with the NOJ group. The UI-imp group had a deeper MSD that was related to a greater backward sulcus inferior and forward soft tissue pogonion position than the Non-imp group. OJ severity was not significantly associated with the presence of UI-imp. A greater OJ was correlated with a deeper MSD and a greater LLeversion, LCTA, and ULS. OJ and OB can be used to predict LLeversion.

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PUNYANIRUN, K. & CHAROEMRATROTE, C. Influencia de la severidad del resalte y el pinzamiento del incisivo superior en el labio inferior en pacientes esqueléticos de Clase II. *Int. J. Morphol., 43(1)*:294-303, 2025.

RESUMEN: El objetivo de este estudio fue investigar la influencia de la severidad del resalte (OJ) y el pinzamiento del incisivo superior (UI-imp) en el labio inferior (LL). Ciento quince radiografías de pacientes esqueléticos de Clase II se agruparon de acuerdo con la severidad del OJ: OJ normal (NOJ/n = 25), OJ moderadamente excesivo (MEOJ/n = 45) y OJ severamente excesivo (SEOJ/n = 45). El UI-imp se clasificó dentro de los sujetos con OJ excesivo (EOJ) de acuerdo con la presencia y ausencia de UI-imp en el LL: UI-imp (n = 50) y sin pinzamiento (Non-imp) (n = 39). Se compararon y analizaron las características esqueléticas, dentales y de los tejidos blandos para determinar las correlaciones. Se generaron modelos de predicción. La eversión del labio inferior (LLeversion), el grosor del labio inferior bermellón (VLLT) y la profundidad del surco mentolabial (MSD) fueron significativamente mayores en el SEOJ que en el NOJ. Estas variables del LL empeoraron a medida que aumentaba la gravedad del OJ. El OJ se correlacionó significativamente de forma positiva con la LLeversion y la MSD y negativamente con la tensión del labio superior (ULS), el ángulo labio-mentón-garganta y la posición más retrasada del LL. Los sujetos con UI-imp mostraron una gravedad del OJ similar a la del grupo sin imp. El grupo UI-imp mostró un surco inferior significativamente más retrasado y una MSD más profunda. SNB, FMA, OJ, OB, UI y LI contribuyeron a los modelos de predicción. Los pacientes con SEOJ mostraron una LLeversion, VLLT y MSD significativamente mayores, mientras que los que tenían UI-imp mostraron una MSD aumentada acompañada de un surco inferior más retrasado en comparación con los que no lo tenían. Se puede esperar una mejora en la morfología de los labios y la armonía entre el labio y el mentón con la reducción de la protrusión de los incisivos externos y de la impronta interdental.

PALABRAS CLAVE: Labio; Protrusión de incisivos; Sobremordida horizontal; Maloclusión, Clase II de Angle.

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