Changes in lips, cheeks and tongue pressures after upper incisor protrusion in Class II division 2 malocclusion: a prospective study

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Abstract

Background: The etiology of Class II division 2 (CII/2) malocclusion focuses on heredity; however lip, cheek, and tongue pressures that are associated with the environmental effect are considered to have an effect. The aim of this study was to evaluate the relation between perioral pressures and the upper incisor inclination in CII/2 malocclusion.

Methods: Twenty patients (8 females, 12 males; mean age 10.29 ± 0.90 years) with CII/2 malocclusion were included in the study group, and 15 patients (5 females, 10 males; mean age 10.56 ± 1.06 years) with Class I malocclusion were included. The upper incisors were protruded with a utility arch (0.016 × 0.022 in. blue elgiloy wire). Perioral pressure assessment was made with the Iowa Oral Pressure Instrument. Upper lip pressure, lower lip pressure, vertical lip pressure, left-right buccal pressures, swallowing, and maximum tongue pressures were measured. Repeated measure ANOVA was used to test the intragroup differences. Intergroup comparisons were made using two-way repeated measure ANOVA with Bonferroni correction. Relationships between the variables were analyzed using rank correlation (Spearman’s rho). The significance for all statistical tests was predetermined at p < 0.05.

Results: A significant change occurred in the upper lip pressure, lower lip pressure, and vertical lip pressure; however, significant difference was not found between the groups. Upper lip pressure increased significantly in both groups. In the CII/2 group, lower lip pressure increased after protrusion and decreased after retention, while vertical lip pressure decreased and then increased significantly. Left buccal pressure changes between the groups were not parallel. Right buccal pressure, swallowing, and maximum tongue pressure changes were not statistically significant. Statistically significant correlation was found between U1-NA (mm) and vertical lip pressure (r = -0.467).

Conclusions: In the CII/2 group, upper lip pressure increased only in retention. Lower lip pressure increased and vertical lip pressure decreased after protrusion. Nevertheless, these changes did not remain stable after the retention period. The difference between groups was not statistically significant at the end of retention.

Keywords: Class II division 2 malocclusion, Perioral pressure, Incisor position
Background

The identification of the etiology is quite important for the success of the orthodontic treatment. In the etiology of Class II division 2 (CII/2) malocclusion, genetics is accepted to be the most important etiologic factor. In studies among twins and triplets, strong evidences were obtained regarding the fact that genetics is the fundamental etiologic factor in the development of CII/2 malocclusion [1–3], though other etiologic factors are lip, cheek, and tongue-related environmental factors. Previous studies have shown that the lips and cheeks, rather than the tongue, are the most important environmental factors of teeth position [4–6]. For stable treatment results, it is necessary to determine the effects of those factors in malocclusion.

Lower lip resting pressure is indicated to be more affective on the position of the upper incisors rather than the upper lip [5, 7]. In some studies, high lip line was shown as the reason behind the retroclined position of the upper incisors [8–11], while in others, the hyperactive lip or mentalis muscle were shown as the reason [12–14]. It has been shown that for individuals with CII/2 malocclusion exposed to significantly higher resting lip pressure than those with Class I malocclusion, the high lower lip line and its pressure were found to be related to the retroclination of the upper incisors in CII/2 malocclusion [10]. Oppositely, in another study, it was mentioned that the pressure from the lips is a result of the incisor position [7].

In the early treatment of CII/2 malocclusion, correcting the molar relationship and inclination of the upper incisors are recommended for the initial phase of treatment. Several appliances such as cervical headgear, removable appliances with anterior bite block, or fixed appliances can be used to correct the malocclusion. The study examining the effects of the cervical headgear on tongue pressure is present in the literature [15]. However, there are no clinical studies examining the effects of fixed-treatment mechanics, mentioned above, on perioral soft tissues yet.

The purposes of our study were to evaluate the changes in perioral pressures after protruding the upper incisors and to investigate if there is any relationship between the upper incisor inclination and perioral pressure changes. The null hypothesis is that protruding the upper incisors does not change the perioral pressures.

Methods

This prospective study was approved by the Ethics Committee of Hacettepe University with the approval number KA-15027. The individuals and their parents were informed about the treatment process, and all of them signed consent forms voluntarily.
A nickel titanium levelling utility arch was applied to the upper molar teeth. Conventional brackets of 0.018-in. transpalatal arch for increasing the anchorage of the teeth were bonded to the upper incisors. A 0.016-in. and/or 0.016 × 0.022-in. blue elgiloy wire was applied. The subjects were observed every 4 weeks. In order to determine if there is enough protrusion, the inclination of the incisors was evaluated clinically. Moreover, whether there was an interference between upper and lower incisors or not was controlled by bringing the mandibula towards the Class 1 molar-canine tooth relation. When enough protrusion was achieved, a Hawley retainer was applied during the 6-month retention period.

### Statistical analysis

SPSS Statistics software (version 21, IBM Corp, Armonk, NY) was used for the analysis of the data. The normality of the variables is evaluated with the Kolmogorov-Smirnov test. In repetitious measurements, the intra-observer reliability was evaluated with intra-class correlation coefficient. All cephalometric measurements were realized by the first author, and the measurements of five patients were repeated within 15 days. In order to evaluate the reliability of the perioral pressures, the measurements that have been repeated before were used.

A power calculation indicated that the achieved power for the study was 0.98. The descriptive statistics were expressed as mean ± standard deviation for continuous variables. The two groups were evaluated using the independent sample t test in terms of quantiative variables and chi-square test in terms of categorical variables. In order to observe the difference of the variables within the group according to the time frames, repeated measure ANOVA was utilized. Two-way repeated measure ANOVA was used to examine the main effects of the malocclusion groups within the treatment stages and the interaction effects between them for the pressure measurements. The Bonferroni test was used as post hoc multiple comparisons. Spearman rho correlation coefficient was calculated to find any correlation between the upper incisor position and pressure measurements. The results for \( p < 0.05 \) were accepted to be significant statistically.

### Results

The data is distributed normally according to the Kolmogorov-Smirnov normality test. While the intra-class correlation coefficient for cephalometric measurements is between 0.972 and 1.000, for the perioral pressure, measurements are between 0.924 and 0.986. In terms of sex distribution, there was no significant difference between the study and control groups (\( p > 0.05 \)). At the same time, no statistically significant difference between the groups in terms of starting age of treatment could be identified (\( p > 0.05 \)). The duration of orthodontic treatment was calculated as 4 months,
retention period as 6 months, and the total duration of treatment as 10 months.

Cephalometric measurements are shown in Table 1. All parameters about upper incisor inclination (U1-SN angle, U1-NA angle, and U1-NA distance) increased significantly (p < 0.001, T1-T0, T2-T0, Table 2).

There are statistically significant changes observed for the measurements of ULP (p < 0.001), LLP (p < 0.01), and VLP (p < 0.001) (Table 3). The interaction between malocclusion and treatment was seen in LLP, VLP, and LBP (p < 0.01) (Table 3).

The difference between the groups was observed in LBP at the beginning of treatment (p < 0.05, T0, Table 4) and in VLP after the protrusion (p < 0.05, T1, Table 4).

The perioral pressure changes in different treatment stages between the study and the control group are shown in Table 5. ULP increased significantly after the retention period in the study group (p < 0.01, T2-T1) and also in the control group (p < 0.05, T2-T1). These increases for both groups remained stable at the end of the study (p < 0.05 for the study group, p < 0.01 for the control group, T2-T0). In the study group, LLP increased after protrusion (p < 0.01, T1-T0) and then decreased back to the initial values after the retention period (p < 0.001, T2-T1). Meanwhile, VLP decreased after protrusion (p < 0.01, T1-T0) and then increased back significantly after the retention period (p < 0.01, T2-T1). While, in the control group, VLP increased during the study and it was observed that at the end of the study, the value was statistically significant (p < 0.01, T2-T0). Moreover, LBP decreased significantly after protrusion in the study group (p < 0.01, T1-T0). The significance has not been determined at the RBP, STP, and MTP measurements (p > 0.05).

The relationship between the changes in the inclination of upper incisors (U1-SN angle, U1-NA angle, U1-NA distance) as well as the changes in the ULP, LLP, and the VLP were examined after the protrusion and retention periods. The decrease in the VLP (1.57 kPa) had a negative and moderate correlation (correlation coefficient -0.467, p < 0.05) with the increase in the U1-NA distance (6.29 mm), after the protrusion period (T1-T0, Table 6). The significance has not been found between the remaining parameters (p > 0.05).

**Discussion**

Perioral structures play important roles in the development of either a normal occlusion or a malocclusion. Soft tissues like the lips, cheeks, and tongue affect hard tissues and orthodontic treatment results by perioral pressures, muscle forces, and periodontal attachments. Therefore, soft tissue limitations should be assessed more precisely by orthodontists, and they should consider not only the genetics but also the environmental factors.

According to the balance theory defined by Weinstein et al. [16], the teeth are balanced by the tongue from the inside and by the lips and cheeks from the outside. At the same time, even though the magnitude of force is low, it may cause a movement in the teeth when applied for a sufficient amount of time [17–19]. Graber [20] stated that the changes observed in the muscle functions may change the normal morphology or may compound the current malocclusion where he examined the muscle morphologies of the Class I, Class II, and Class III malocclusions. Evaluations regarding the soft tissues are very important for determining the malocclusion etiology and the stability of the orthodontic treatment. Thus, in this study, we aimed for clarifying the relationship between the upper incisor protrusion and perioral pressures.

In the evaluation of the soft tissues, it is possible to investigate thickness or volume measurements as well as the electromyographic or electrodynamic measurements. Applying electrodynamic measurement techniques with strain gauges is a reliable method for evaluating soft tissue forces and pressures [21–31]. Lindeman and Moore [32], comparing three different methods of evaluating the perioral pressure and the force, maintained that the lips cause fluid-like pressure, and thus, they should be evaluated using devices that are sensitive to pressure

### Table 1 Cephalometric measurements of the study group

|          | T0      | T1      | T2      | p       |
|----------|---------|---------|---------|---------|
| U1-SN (°)| 89.49 ± 5.69 | 108.91 ± 5.25 | 106.71 ± 6.00 | 0.000*  |
| U1-NA (°)| 8.69 ± 5.37  | 28.70 ± 4.67  | 26.41 ± 3.99  | 0.000*  |
| U1-NA (mm)| -1.39 ± 1.62 | 4.90 ± 1.51   | 4.65 ± 1.24   | 0.000*  |

*p < 0.001

### Table 2 Cephalometric measurement changes of the study group in different treatment stages

|          | T1-T0          | T2-T1          | T2-T0          |
|----------|----------------|----------------|----------------|
| U1-SN (°)| 19.43 ± 1.47   | -2.21 ± 0.97   | 17.22 ± 1.43   | 0.000*  |
| U1-NA (°)| 20.02 ± 1.45   | -2.30 ± 0.90   | 17.72 ± 1.31   | 0.000*  |
| U1-NA (mm)| 6.29 ± 0.43    | -0.26 ± 0.28   | 6.03 ± 0.30    | 0.000*  |

*p < 0.001
Comparison of pressure measurements according to the treatment stages between the study and control groups

Table 4 Comparison of pressure measurements according to the treatment stages between the study and control groups

|                        | Study group Mean ± SD | Control group Mean ± SD | p     | Study group Mean ± SD | Control group Mean ± SD | p     | Study group Mean ± SD | Control group Mean ± SD | p     |
|------------------------|-----------------------|-------------------------|-------|-----------------------|-------------------------|-------|-----------------------|-------------------------|-------|
| Upper lip pressure (kPa) | 22.13 ± 3.23          | 22.17 ± 2.70            | 0.960 | 21.68 ± 2.32          | 23.17 ± 2.13            | 0.060 | 24.65 ± 2.90          | 25.69 ± 3.96            | 0.377 |
| Lower lip pressure (kPa) | 23.15 ± 4.24          | 23.15 ± 4.61            | 0.956 | 26.90 ± 5.95          | 24.20 ± 4.93            | 0.163 | 22.95 ± 4.01          | 25.73 ± 5.80            | 0.103 |
| Vertical lip pressure (kPa) | 9.38 ± 2.38           | 8.97 ± 1.92             | 0.593 | 7.81 ± 2.52           | 9.81 ± 1.75             | 0.013*| 9.63 ± 2.79           | 11.11 ± 2.30            | 0.105 |
| Left buccal pressure (kPa) | 21.93 ± 3.35          | 18.93 ± 3.21            | 0.012*| 19.00 ± 2.69          | 20.22 ± 2.88            | 0.205 | 20.86 ± 4.07          | 21.15 ± 3.07            | 0.820 |
| Right buccal pressure (kPa) | 20.90 ± 3.18          | 20.00 ± 3.26            | 0.419 | 19.71 ± 3.34          | 20.73 ± 3.10            | 0.364 | 20.28 ± 4.37          | 19.66 ± 2.99            | 0.643 |
| Swallowing tongue pressure (kPa) | 23.00 ± 6.71          | 26.11 ± 12.09           | 0.339 | 24.93 ± 7.82          | 24.75 ± 8.11            | 0.948 | 23.00 ± 8.70          | 22.38 ± 5.06            | 0.807 |
| Maximum tongue pressure (kPa) | 46.48 ± 7.00          | 49.55 ± 8.75            | 0.257 | 44.46 ± 8.49          | 50.11 ± 8.05            | 0.055 | 46.18 ± 9.24          | 49.44 ± 7.26            | 0.267 |

*<p < 0.05
determined by the increased LLP in CII/2 malocclusion. In one of the studies that investigated the effect of increased overjet in perioral pressures, it was observed that LLP increased [7], while in another study, VLP decreased because tightening of the lips became harder [39]. These findings are compatible with the findings of our study. However, these studies had a cross-sectional study design, and individuals with an increased overjet were included. Meanwhile, in the control group, VLP did not increase significantly after protrusion and then significantly after the protrusion period. Due to these changes, significant difference occurred at the end of protrusion between the two groups. In fact, although not significant, LLP also increased in the control group. All these lip pressure increases observed in the control group might be described as mentioned above in ULP.

The only correlation between the incisor inclination and the lip pressures was found between the increase of the U1-NA distance and the decrease of VLP. This correlation, even though statistically significant, was moderate. However, a significant correlation between the increase of VLP and the decrease of upper incisor inclination was not observed after the retention. Therefore, VLP which did not remain stable after retention was not associated with the mild relapse of upper incisor protrusion. Such as soft tissue morphology changes, other factors that may be effective on the perioral pressures need to be investigated in further studies. Thüer and Ingervall [7] determined that ULP was correlated with the morphology of the lips, while Di Fazio et al. [40] found a significant correlation between ULP and age.

This is the first study to evaluate the perioral pressure changes in terms of lips by IOPI. Furthermore, IOPI can be considered as a diagnostic tool for malocclusions and the progression of myofunctional exercises. Hence, orthodontists can use IOPI for the malocclusions arising from bad oral habits in a practical way. The only limitation of this prospective study was that transitions in mixed dentition might affect the perioral pressure measurements.

### Table 5 Statistical analysis of the pressure changes in different treatment stages between the study and control groups

|                          | T1-T0          | T2-T1          | T2-T0          |
|--------------------------|----------------|----------------|----------------|
|                          | Mean difference ± SD | p              | Mean difference ± SD | p          | Mean difference ± SD | p          |
| Upper lip pressure (kPa) | Study group     | −0.45 ± 0.57   | 1.000          | 2.97 ± 0.75     | 0.001**      | 2.52 ± 0.83   | 0.014*       |
|                          | Control group   | 1.00 ± 0.66    | 0.418          | 2.51 ± 0.87     | 0.020*       | 3.51 ± 0.96  | 0.003**      |
| Lower lip pressure (kPa) | Study group     | 3.75 ± 1.03    | 0.003**        | −3.95 ± 0.79    | 0.000***     | −0.20 ± 0.98 | 1.000        |
|                          | Control group   | 1.13 ± 1.19    | 1.000          | 1.54 ± 0.91     | 0.308        | 2.67 ± 1.13  | 0.072        |
| Vertical lip pressure    | Study group     | −1.57 ± 0.39   | 0.001**        | 1.82 ± 0.49     | 0.002**      | 0.25 ± 0.47  | 1.000        |
| (kPa)                    | Control group   | 0.85 ± 0.46    | 0.216          | 1.29 ± 0.56     | 0.084        | 2.13 ± 0.54  | 0.001**      |
| Left buccal pressure (kPa)| Study group    | −2.93 ± 0.71   | 0.001**        | 1.87 ± 0.81     | 0.084        | −1.07 ± 0.79 | 0.565        |
|                          | Control group   | 1.29 ± 0.82    | 0.375          | 0.93 ± 0.94     | 0.980        | 2.22 ± 0.92  | 0.062        |
| Right buccal pressure    | Study group     | −1.18 ± 0.63   | 0.203          | 0.57 ± 0.80     | 1.000        | −0.62 ± 0.88 | 1.000        |
| (kPa)                    | Control group   | 0.73 ± 0.72    | 0.953          | −1.07 ± 0.92    | 0.760        | −0.33 ± 1.01 | 1.000        |
| Swallowing tongue pressure (kPa) | Study group | 1.93 ± 1.49    | 0.609          | −1.93 ± 1.72    | 0.807        | 0.00 ± 1.82  | 1.000        |
|                          | Control group   | −1.36 ± 1.72   | 1.000          | −2.38 ± 1.99    | 0.720        | −3.73 ± 2.10 | 0.255        |
| Maximum tongue pressure  | Study group     | −2.02 ± 1.64   | 0.678          | 1.72 ± 1.39     | 0.678        | −0.30 ± 1.73 | 1.000        |
| (kPa)                    | Control group   | 0.56 ± 1.89    | 1.000          | −0.67 ± 1.61    | 1.000        | −0.11 ± 2.00 | 1.000        |

*p < 0.05, **p < 0.01, ***p < 0.001

### Table 6 Evaluation of the relationship between the upper incisor inclination and pressure measurements

|                          | U1-SN (°) r  | U1-NA (°) r  | U1-NA (mm) r |
|--------------------------|--------------|--------------|--------------|
| Upper lip pressure (kPa) |                             |              |              |
| T1-T0                    | −0.024       | 0.920        |              |
| T2-T1                    | −0.132       | 0.578        |              |
| Lower lip pressure (kPa) |                             |              |              |
| T1-T0                    | −0.312       | 0.181        | −0.063       |
| T2-T1                    | 0.099        | 0.679        | 0.105        |
| Vertical lip pressure    |                             |              |              |
| (kPa)                    | 0.038        | 0.873        | −0.045       |
| T1-T0                    | 0.095        | 0.690        | 0.849        |

*p < 0.05
It has been known that soft tissues affect skeletal and dentoalveolar hard tissues during growth. Our findings showed that changes that occurred in the anterior teeth had a temporary effect on the soft tissues. Therefore, it should be noted that permanent changes could not be achieved in soft tissue pressures after upper incisor protrusion and relapse resulting from soft tissue pressures should always be kept in mind. In further studies, perioral pressure changes can be examined by including different malocclusions.

Conclusions
Permanent changes did not occur in perioral pressures with upper incisor protrusion in CII/2 malocclusion. In addition, there is a negative moderate correlation between the protrusion of upper incisors and the vertical lip pressure.

Abbreviations
CII/2: Class II division 2 malocclusion; IOP: Iowa Oral Performance Instrument; LBP: Left buccal pressure; LLP: Lower lip pressure; MTP: Maximum tongue pressure; RBP: Right buccal pressure; STP: Swallowing tongue pressure; ULP: Upper lip pressure; VLP: Vertical lip pressure

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Availability of data and materials
The data of this study is not available.

Authors’ contributions
IP participated in treating the patients, collecting and interpreting the data, and writing the manuscript. MA participated in designing the study protocol and revising the manuscript critically for intellectual content. Both authors read and approved the final manuscript.

Ethics approval and consent to participate
The study was reviewed and approved by the Ethical Committee of Hacettepe University (Ankara, Turkey) with the approval number KA-15027. All procedures followed adhered to the Declaration of Helsinki guidelines. All patients and their parents were informed of the purpose of this study and signed an informed consent form voluntarily.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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