Impact of Oral Habits and Buccal Frenulum on Gingival Microcirculation in Children: Findings and Clinical Significance

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Abstract

**Background.** Oral mucosal abnormalities such as abnormal lip frenulum, buccal frenulum, ankyloglossia are commonly observed in a routine dental practice. The close anatomical and functional relationship between the gingiva and the alveolar bone determines the significance of abnormal mucosal structures in the development of malocclusions and periodontal diseases. Oral habits are more prevalent in childhood; however, they can persist into adolescence and adulthood, potentially leading to dentofacial impairments and malocclusions. Therefore, there is a growing interest in understanding oral mucosal blood flow in the presence of oral habits and abnormal mucosal structures, as their combined effects may have a synergistic influence on the development of maxillomandibular anomalies.

**Aim.** This study was aimed to investigate age-depended parameters of gingival microcirculation in children with buccal frenulum, oral habits, and maxillomandibular anomalies.

**Methods.** This cross-sectional study involved 45 apparently healthy children and 180 children with oral habits, buccal frenulum, and maxillomandibular anomalies, divided into 3 age groups (ages 9 to 12, 12 to 15, and 15 to 17 years). Oral mucosal blood flow was assessed using a rheograph DX (Kharkiv, Ukraine) by measuring qualitative characteristics and quantitative parameters such as the vascular tone index (VTI), venous outflow index (VOI), peripheral resistance index (PRI), extensive blood flow index (EBFI), and rheographic index (RI). Statistical analysis included Spearman's correlation, a Kruskal-Wallis H test, and a Dunn's post-hoc test.

**Results.** The study revealed a significantly higher VTI in all patient groups, increasing with age and reaching +80.54% in the oldest age group compared to the respective control group. This elevation was accompanied by a moderate correlation enhancing the PRI (+4.61% in 9-12-year-old group to +33.42% in 15-17-year-old group). Furthermore, the VOI exhibited a noteworthy and age-dependent increase; however, there was a notable reduction in the RI (-41.10% to -59.70%) and EBFI values (-35.54% and -37.70% versus -23.97% in the youngest age group).

**Conclusions.** This study demonstrated a relationship between oral habits, buccal frenulum, and age-dependent disturbance of gingival microcirculation in children. The findings suggest that chronic traumatization due to oral habits and abnormal mucosal structures lead to increased vasoconstriction and impaired vessel elasticity. Early intervention and management of such category of patients are crucial for preserving optimal gingival microcirculation.

**Keywords**
Vestibule of the Mouth; Oral Habits; Buccal Frenulum; Gingival Microcirculation; Maxillomandibular Anomalies

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**Introduction**

In a routine dental clinical practice, commonly observed oral mucosal lesions are abnormal lip frenulum, buccal frenulum, ankyloglossia, and shallow vestibule [1, 2]. The normal position of oral mucosal structures is crucial for preventing gingival retraction [3], forming malocclusions [4], and developing periodontal diseases [5].

The gingiva has strong anatomical and functional association with the alveolar bone. Systemic diseases, oral mucosal lesions such as lip/tongue tie or shallow vestibule may potentially result in gingival recession [6, 7] and provoke blood flow reduction. Due to anatomically close relationship to alveolar bones, this reduction will affect normal supply of periodontal tissues and lead to alveolar bone remodeling [8–10]. Moreover, an abnormal frenulum is an important issue in orthodontic treatment and can be a risk factor for malocclusions, delayed eruption [11, 12].

Oral habits are observed among children in different societies; however, their prevalence significantly differ [13–15]. Usually, these habits are reduced with age; however, they are still present among patients with primary dentition as well as mixed and permanent ones [16, 17]. Moreover, research indicates that the onset of oral habits can potentially be associated with anxiety and stress conditions, including Covid-19, in both adults and adolescents [18, 19]. Oral habits may develop on the psycho-emotional background and lead to the impairment of the dentofacial region as well [15]. The findings of a cross-sectional epidemiologic study in Southern Italy have demonstrated an association between oral habits, gender, and temporomandibular disorders among adolescents [20]. In addition, oral habits significantly increase the risk of malocclusion. A relationship has been established between oral habits, spacing, crowding, and increased overjet, while tongue thrusting has been found to significantly increase the risk of malocclusion severity in 6-12-year-old children in Nigeria [13]. A high risk of developing open bite has been found among children with sucking habits in Java and Brazil [21, 22].

In recent decades, the assessment and restoration of oral mucosal blood flow have gained growing attention [23]. Investigating mucosal blood supply is of great importance in children and adolescents with a combination of mucosal lesions and oral habits. The combination of these two factors can potentially result not just in a mere summation of their individual effects, it can exert a synergistic influence on the development of maxillomandibular anomalies [9, 11–13]. Left untreated, these conditions lead to significant blood flow disturbance and mechanical trauma, which over time leads to gingival recession in adolescents [9, 10].

While most studies highlight the importance of assessing oral mucosal blood flow, there is limited research specifically focused on age-dependent parameters of oral mucosal blood flow in children with oral mucosal lesions. Therefore, the aim of this study was to assess age-dependent parameters of oral mucosal blood flow in children with buccal frenulum on the background of oral habits and maxillomandibular anomalies. By addressing this research gap, we aim to contribute to the development of targeted treatment strategies for children with oral mucosal lesions and dentofacial anomalies.

**Materials and Methods**

**Study Design**

This cross-sectional study was performed at the Department of Therapeutic Dentistry, Ivano-Frankivsk National Medical University, Ivano-Frankivsk, Ukraine, between April 2014 and June 2022.

**Study Population**

The study involved two groups: the main group consisted of 180 patients; the control group comprised 45 individuals. Each group was divided into subgroups based on age, with 60 patients in each subgroup of the main group and 15 individuals in each subgroup of the control group. There was no difference in gender diversity between the subgroups and age groups (p > 0.05) (Fig. 1). The age ranges for the subgroups were (ICD, [https://icd.who.int/](https://icd.who.int/)):

- Group I: 9-12 years
- Group II: 12-15 years
- Group III: 15-17 years

![Figure 1. Gender distribution of study population.](image)

**Patients**

The main group (180 patients) was formed by children who met eligibility criteria:

- age of 9-17 years;
- presence of buccal frenulum;
- oral habits, including finger and/or tongue sucking, lip biting > 5 times per day, head leaning on hard objects (such as hands or bed frames), sitting near monitors with an open mouth while breathing through the nose, sleeping with hands under the head and/or not on an orthopedic pillow;
- presence of maxillomandibular anomalies;
- no history of skull fractures.
The control group included 45 subjects who met the following eligibility criteria:

- age of 9-17 years;
- normal depth of the oral vestibule;
- no periodontal diseases;
- no maxillomandibular anomalies, facial asymmetries, congenital oral mucosal malformation;
- no oral habits;
- no history of skull fractures.

Assessment

The assessment of oral mucosal blood flow was performed using a rheograph DX (Kharkiv, Ukraine) (Fig. 2) with dental electrodes developed by the authors’ team in collaboration with the manufacturer of the rheograph for the purposes of the current study. Rheograms were recorded with the patient in a sitting position, and the electrode was placed on the attached gingiva in the projection of the frontal teeth. Two additional electrodes were fixed on the wrist. Prior to the assessment, blood pressure measurements were taken to prevent the influence of systemic cardiovascular changes on the interpretation of local rheograms. The rheographic curves were evaluated based on qualitative characteristics and quantitative parameters, including the vascular tone index (VTI), venous outflow index (VOI), peripheral resistance index (PRI), reduction in the extensive blood flow index (EBFI), and rheographic index (RI) according to manufacturer instructions.

![Figure 2. Rheograph (a) and positioning of rheographic electrodes (b).](image)

Statistical Analysis

Statistical processing of the results was performed using Statistica 12.0 software package. The comparisons of gender percentage between the subgroups and age groups were performed using the Chi-square test. Data distribution was assessed using the Kolmogorov-Smirnov test of normality. Mean values and standard errors were calculated for continuous variables. Correlation between parameters was analyzed using the Spearman’s correlation coefficient, the Kruskal-Wallis H test, and the Dunn’s post-hoc test. Significance was set at \( p < 0.05 \).

Results

A qualitative analysis of the rheographic curves in control group patients revealed a high amplitude and rapid ascent to the top of the wave, in contrast to the isoline (Fig. 3). However, the amplitude of the rheographic curve was found to be reduced across all age groups in main group patients. Typically, the wave exhibited a bicuspid morphology with a smoothed profile and a sloping ascent, indicative of prolonged venous outflow.

In control group patients, the estimating parameters tended to remain relatively stable or slightly changed with age, but not significantly \( (p > 0.05; \text{Table 1}) \). However, in main group patients, the VTI, PRI, and VOI demonstrated a valuable increase with age when compared to their respective control groups. The EBFI and RI expressed gradual decrease with increasing age when compared to their respective controls.

**Table 1.** Age-dependent parameters of oral mucosal blood flow in patient groups (Mean±SE).

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Group</th>
<th>VTI, %</th>
<th>PRI, %</th>
<th>VOI, %</th>
<th>EBFI, Om/sec</th>
<th>RI, c.u.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (9-12)</td>
<td>(n=60)</td>
<td>18.35±1.44a</td>
<td>72.43±1.18a</td>
<td>15.22±0.005b</td>
<td>0.092±0.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>15.53±1.03</td>
<td>66.23±0.32</td>
<td>11.13±0.005b</td>
<td>0.121±0.73</td>
<td></td>
</tr>
<tr>
<td>II (12-15)</td>
<td>(n=60)</td>
<td>20.35±1.25b</td>
<td>84.18±0.40b</td>
<td>17.61±0.005b</td>
<td>0.078±0.35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>15.58±1.04</td>
<td>71.05±0.54</td>
<td>11.26±0.005b</td>
<td>0.121±0.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>1.28±0.17</td>
<td>71.05±0.18</td>
<td>11.26±0.005b</td>
<td>0.121±0.72</td>
<td></td>
</tr>
<tr>
<td>III (15-17)</td>
<td>(n=60)</td>
<td>24.12±1.14c</td>
<td>91.06±0.54c</td>
<td>21.02±0.005b</td>
<td>0.076±0.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>14.32±0.21</td>
<td>68.25±0.18</td>
<td>11.09±0.005b</td>
<td>0.122±0.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=15)</td>
<td>1.14±0.17</td>
<td>68.25±0.12</td>
<td>11.09±0.005b</td>
<td>0.122±0.72</td>
<td></td>
</tr>
</tbody>
</table>

Notes: c.u. - conditional units. Superscript letters indicate statistically significant differences between patient groups and respective controls. The EBFI and RI expressed gradual decrease when compared to the control group \( (p<0.05) \).

Correlation analysis showed relatively stable and statistically significant relationships between the assessed indices and an increase in age (Table 2). However, most relations were weak, except for the correlations of the PRI with the other indices.

**Table 2.** Within-group correlation matrix of rheographic indices for patient groups (Mean±SE).

<table>
<thead>
<tr>
<th>Group (years)</th>
<th>Index</th>
<th>VTI</th>
<th>PRI</th>
<th>VOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (9-12)</td>
<td>PRI</td>
<td>0.42±0.20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VOI</td>
<td>0.29±0.15</td>
<td>0.43±0.20</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>EBFI</td>
<td>-0.24±0.15</td>
<td>-0.36±0.19</td>
<td>-0.29±0.18</td>
</tr>
<tr>
<td>II (12-15)</td>
<td>VTI</td>
<td>0.42±0.22</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PRI</td>
<td>0.29±0.18</td>
<td>0.43±0.21</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VOI</td>
<td>-0.24±0.16</td>
<td>-0.36±0.21</td>
<td>-0.29±0.17</td>
</tr>
<tr>
<td>III (15-17)</td>
<td>VTI</td>
<td>0.42±0.21</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PRI</td>
<td>0.29±0.18</td>
<td>0.43±0.20</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>VOI</td>
<td>-0.24±0.15</td>
<td>-0.36±0.15</td>
<td>-0.29±0.14</td>
</tr>
</tbody>
</table>

Notes: all correlations are statistically significant, \( p<0.05 \).
Discussion

This study was aimed to investigate oral mucosal blood flow in children with oral habits and buccal frenulum. The findings of the study demonstrated significant differences in blood flow parameters between patient and control groups. Although the investigated quantitative indices had weak correlations with each other, they exhibited a strong dependence on the age factor.

Thus, the VTI values were significantly higher in all patient groups compared to the control group, and these values increased with age. In the oldest age group, the VTI exceeded the control values by 80.54%, indicating a sufficient resistance to blood flow in the oral mucosal vessels within this specific patient group (Table 1). Such increased VTI values suggested increasing vasoconstriction or decreasing vasodilatation of the oral mucosal blood vessels [24].

The PRI demonstrated an increase in values depending on age; however, the magnitude of this increase was smaller compared to the increase observed in the VTI. The difference in the PRI values between patients and controls became more pronounced with increasing age (+4.61% in 9-12-year-old group to +33.42% in 15-17-year-old group compared to the respective controls). An elevation in the PRI accompanied by an increase in the VTI (Table 1) and their moderate correlation in all groups (Table 2) suggested that the blood vessels in the oral mucosa were undergoing greater constriction [25], potentially due to impaired vessels elasticity resulting in reduced blood flow [26]. Furthermore, a substantial increase in the VOI (ranging from 15.67% to 89.61%) along with qualitative changes in the rheographic curves (Fig. 3) suggested inadequate venous drainage. In addition, moderate correlations between the PRI, VTI, and VOI indicated that the PRI might be a more reliable indicator of age-related changes in vascular function compared to the other indices.

At the same time, a sufficient reduction in the RI (-41.10% to -59.70%) indicated low magnitudes of the rheographic curves and suggested that collateral circulations in the oral mucosa were not involved or activated [27]. On the other hand, there was a reduction in blood flow, which became more pronounced in the middle and oldest age groups (EBFI values -35.54% and -37.70% versus -23.97% in 9-12-year-old group) on the background of increasing the PRI, which was determined by features of microcirculatory architecture of the oral mucosa [28, 29] and might potentially lead to increased risk of mucosa lesions [30].

The significant changes observed in the assessed parameters of blood flow could be attributed to chronic trauma of the mucosa resulting from oral habits and oral mucosal lesions [24, 31]. It is important to note relatively stable values in control groups compared to the prominent changes seen in patient groups (Table 1). Considering the age-dependent decrease in the ability to maintain blood flow in the gingiva [32], along with the presence of maxillomandibular anomalies in assessed subjects, it is likely that determined changes in blood flow dynamics will be amplified, thereby increasing the risk of periodontal diseases [1, 5]. Furthermore, the presence of ischemia in the gingiva during orthodontic treatment of maxillomandibular anomalies could lead to additional trauma of the oral mucosa [33]. Therefore, it further emphasizes the importance of restoring adequate microcirculation, which is equally significant as preventing occlusal trauma [33, 34].
**Limitations**

This study limitations are inherent to its design and should be taken into consideration when interpreting the findings. Firstly, it is a single-center study, which limits the generalizability of the results to other settings or populations. Additionally, the observed blood flow disturbances can only be extrapolated to patients meeting the specific eligibility criteria outlined in the study. Secondly, this study is cross-sectional in design and focuses on participants aged 9-17 years. Further investigations should be conducted to assess dynamic changes in microcirculation during different stages of childhood. Lastly, it is important to note that the equipment used in this study was specifically developed for the purpose of the research, and using different equipment or techniques may yield different results.

**Conclusions**

The findings of this study provided evidence of a relationship between oral habits, buccal frenulum, and gingival microcirculation in children. The results revealed an age-dependent blood flow disturbance in the oral mucosa marked by increased vasoconstriction and impaired vessel elasticity, which was likely attributed to chronic trauma resulting from oral habits and the presence of abnormal mucosal structures. The observed associations highlight the importance of early intervention and management of oral habits and mucosal lesions to prevent potential complications and maintain optimal gingival microcirculation in children. Further research and targeted treatment strategies are required to improve understanding and clinical outcomes in this direction.

**Ethical Statement**

The study was conducted according to the WMA Declaration of Helsinki and approved by the Ethics Committee of the Ivano-Frankivsk National Medical University.

**Informed Consent**

Written informed consent was obtained from all children’s parents before participating in the study.

**Data Availability**

De-identified and anonymized data supporting the findings of this study are available upon reasonable request.

**Conflict of Interest**

The authors declare no conflicts of interest. However, it should be noted that ZO, as the senior author, is a member of the journal editorial board. ZO’s involvement in this study was limited to study design, critical revision, and final approval of the manuscript, and he did not participate in the editorial process.

**References**


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