The Open Dentistry Journal
DOI: 10.2174/0118742106387759250620074331, 2025, 19, e18742106387759
ISSN: 1874-2106

RESEARCH ARTICLE OPEN ACCESS

Correlation between Salivary pH, Buffer Capacity, and Oral Hygiene in Orthodontic Patients with Non-syndromic Cleft Lip and Palate

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Abstract:

Introduction: Orthodontic patients with cleft lip and palate generally have poor oral hygiene due to residual scar tissue from multiple surgical procedures in the cleft area, which interferes with effective tooth cleaning. Calculus, one of the local etiological factors for periodontal disease, forms under the influence of various factors, including saliva. Notably, salivary pH and buffer capacity play roles in calculus formation. This study aimed to analyze the correlation between salivary pH, buffer capacity, and oral hygiene in orthodontic patients with non-syndromic cleft lip and palate.

Methods: This was a cross-sectional observational analytic study involving orthodontic patients with non-syndromic cleft lip and palate treated at the Orthodontic Specialist Teaching Clinic of Oral and Dental Hospital, Universitas Padjadjaran, Indonesia (n=20). Saliva was collected passively for salivary pH and buffer capacity testing, while oral hygiene was assessed using the OHI-S index by summing the Debris Index (DI) and Calculus Index (CI).

Results: The results of this study showed that 85.71% of the samples had normal pH, and 90.48% had very low buffer capacity. The oral health level of the respondents was in the moderate category based on the OHI-S examination (61.90%). Most of the participants had a good Calculus Index (90.48%) and a moderate value on the Debris Index (57.14%). The statistical test results showed no significant relationship between salivary pH and OHI-S, with a *p*-value of 0.22 ($p > 0.05$). The Debris Index (DI) and Calculus Index (CI) also showed non-significant *p*-values of 0.09 ($p>0.05$) and 0.28 ($p >0.05$), respectively. In contrast, salivary buffer capacity demonstrated a significant positive relationship with the Calculus Index (CI), with a *p*-value of 0.01 ($t<0.05$).

Discussion: Salivary pH does not significantly influence calculus formation, while salivary buffer capacity does influence the Calculus Index (CI) in patients with non-syndromic cleft lip and palate.

Conclusion: This study found a non-significant correlation between salivary pH, buffer capacity, and oral hygiene in orthodontic patients with non-syndromic CLP.

Keywords: Cleft lip and palate, Saliva, pH, Buffer, Oral hygiene, Periodontal disease.

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Cite as: Sayuti E, Laviana A, Evangelina I, Latif D, Manurung C, Mardiati E. Correlation between Salivary pH, Buffer Capacity, and Oral Hygiene in Orthodontic Patients with Non-syndromic Cleft Lip and Palate. Open Dent J, 2025; 19: e18742106387759. http://dx.doi.org/10.2174/0118742106387759250620074331

Received: January 31, 2025
Revised: April 17, 2025
Accepted: May 13, 2025
Published: June 27, 2025

1. INTRODUCTION

Non-syndromic cleft lip and palate is a congenital disorder characterized by incomplete separation of the nasal and oral cavities without any syndromic abnormalities [1]. It is a birth defect that primarily affects the upper lip and hard palate [2]. A cleft lip occurs due to failure of fusion between the frontonasal and maxillary processes, resulting in a cleft of varying extent that may involve the lips, alveolus, and floor of the nose. Meanwhile, the cleft palate results from the failure of fusion of the palatal shelves in the maxillary process, leading to a cleft in the hard and soft palate [3]. CLP develops during the early stages of fetal growth, between the 7th and 12th weeks of pregnancy, due to failed tissue fusion [4, 5].

Children with a cleft palate or palatal cleft commonly experience complications related to malocclusion and dental health. Most adult patients with facial clefts require orthodontic treatment, often involving orthognathic surgery or prosthetic treatment [6]. The use of fixed orthodontic appliances and prostheses before and after a surgical repair in CLP patients creates small hidden areas that reduce the effectiveness of saliva in natural self-cleansing. These appliances and denture bases increase plaque retention and make it difficult for patients to maintain good oral hygiene [7]. As a result, orthodontic treatments can contribute to result in poor oral hygiene and an increased risk of severe dental caries in CLP patients [8].

Zahid *et al*. stated in their study that half of children suffering from cleft lip and palate have poor oral and dental health [9]. Children and adults with cleft lip and/or palate are at increased risk for gingivitis, periodontitis, and carious lesions. Several factors contribute to the challenges in maintaining cleanliness in the cleft area. These include the presence of frenulae, tooth malposition, gingival recession, dental anomalies, and prolonged use of fixed orthodontic appliances [10]. Post-surgical scar tissue resulting from cleft closure procedures and orthodontic treatment further complicates optimal plaque control in patients with cleft lip and palate [11]. Several studies have also reported that children with CLP have poor oral hygiene and a higher prevalence of periodontal disease compared to children without CLP [7]. Davies *et al*. stated that children with CLP had more oral hygiene problems than those without CLP, as indicated by higher levels of plaque, inflammation, and a greater incidence of caries [12].

Oral hygiene in CLP patients is often poor due to the use of intraoral appliances during treatment [13]. The use of rapid maxillary expansion (RME) appliances, fixed appliances with brackets, wires, elastics, and other orthodontic devices creates plaque-retentive areas in the mouth. This increases the challenge of maintaining optimal oral hygiene and increases the risk of plaque accumulation, dental caries, gingivitis, and periodontal problems [14, 15].

Calculus is one of the local etiological factors involved in periodontal disease. It is a mineralized plaque that adheres tightly to the tooth surface and consists of both inorganic components and an organic matrix. Calculus formation begins with the accumulation of dental plaque [16]. Plaque is a collection of bacteria embedded in an organic matrix that adheres tightly to the tooth surface. It is the main causative factor in periodontal disease, while calculus plays a secondary role in this mechanism and acts as a retention surface for more plaque to accumulate, thereby exacerbating tissue damage [12].

One of the factors that influence calculus formation is saliva [17]. Saliva is a complex fluid that contains various mucosal defense factors secreted by different salivary glands, as well as sulcus fluid, glucose, and nitrogen compounds such as urea and ammonia [17, 18]. The pH of saliva typically ranges from 5 to 8. Both the pH and buffering capacity of saliva can affect calculus formation. A high salivary pH can promote calculus formation by increasing the saturation of mineral components in dental plaque [19]. Previous studies have emphasized the importance of an alkaline pH for calcium phosphate precipitation, which enhances plaque mineralization. Variations in plaque pH, expressed in free ionic concentrations, can significantly influence the supersaturation of calcium phosphate precursor phases such as dicalcium phosphate dihydrate (DCPD) and octacalcium phosphate (OCP).

Oral hygiene measurements are used to determine the cleanliness of a person's teeth and mouth [20]. Dental and oral hygiene is generally evaluated using an index. The level of oral hygiene is clinically assessed using the Oral Hygiene Index Simplified (OHI-S) criteria, which evaluates the presence of soft deposits (debris) and hardened deposits (calculus). Plaque retention can be observed on tooth surfaces using disclosing agents [20-22]. The OHI-S measurement consists of two components: the Debris Index (DI) and the Calculus Index (CI). To date, there have been no recent scientific publications examining the oral health of orthodontic patients with non-syndromic cleft lip and palate in relation to salivary pH and buffering capacity. Therefore, this study aimed to investigate the correlation between salivary pH, buffer capacity, and oral hygiene in orthodontic patients with non-syndromic cleft lip and palate.

2. METHOD

2.1. Study Design and Type of Study

This study utilized an observational design and was conducted as a cross-sectional analytical study.

2.2. Sample Size

The sample of this study consisted of 21 orthodontic patients with non-syndromic cleft lip and palate who were treated at the PPDGS Orthodontic Polyclinic, RSGM UNPAD, during the period of June to August 2023. The number of CLP patients receiving orthodontic treatment at RSGM Unpad is very limited, which accounts for the small sample size.

2.3. Selection Criteria

Subjects were selected for this study using a purposive sampling technique based on specific inclusion and exclusion criteria. The inclusion criteria were: patients who were willing to participate in the study; male and female patients with non-syndromic cleft lip and palate undergoing treatment with removable or fixed orthodontic appliances for a minimum of 3 months; and patients aged 10 – 30 years old. The exclusion criteria included patients with diabetes, those

taking systemic medications, pregnant individuals, smokers, alcohol consumers, and those who had consumed acidic substances within the last two hours.

2.4. Ethics Approval

This research received ethical approval from the Research Ethical Committee of Padjadjaran University, No. 531/UN6.KEP/EC/2023.

2.5. Data Collection Methods

Subjects were asked to sit still and relaxed, with their heads slightly lowered and minimal mouth muscle activity. All unstimulated saliva was allowed to pool on the floor of the mouth for 5 minutes. Subjects were then asked to passively collect saliva in a sterile container. The sterile containers with saliva were stored in a cool box at 4º sent to the laboratory for examination. The pH test was conducted using a Lutron PH-208 type pH meter. The buffer capacity of saliva was measured using the titration technique by mixing 1 ml of saliva with 3 ml of 0.005 N HCl. After homogenization, the mixture was measured using the same pH meter (Lutron PH-208) [23]. The measurement results were categorized as follows: very low (0-5), low (6-9), and normal (10-12) [24]. A reliability test was performed by measuring the pH and buffer capacity of saliva in the same samples twice by the same researcher, with calibration of the instruments ensured.

Oral health checks were performed using the Oral Hygiene Index Simplified (OHI-S), developed by Greene and Vermillion [25]. The debris index was measured by examining six tooth surfaces-four posterior teeth and two anterior teeth -using disclosing fluid. The stained areas on the tooth surface were then assessed according to the debris index criteria to determine the presence of debris.

Examinations were performed on six teeth, namely teeth 16, 11, 26, 36, 31, and 46. The buccal/labial surfaces of teeth 16, 11, 26, and 31 were examined, while the lingual surfaces of teeth 36 and 46 were assessed [20]. The OHI-S is the sum of the Calculus Index (CI) and Debris Index (DI) values. The OHI-S score criteria are as follows: *good* (0-1.2), *fair* (1.3-3.0), and *poor* (3.1–6.0) [20]. All subjects provided signed informed consent after an explanation of the study protocol.

2.6. Statistical Method

The statistical method used in this study is the *t*-test and Spearman Coefficient of Rank Correlation, performed by using Excel MegaStat software version 10.6.

3. RESULTS

This study initially involved 26 patients with cleft lip and palate (CLP) who were treated at RSGM Unpad. However, due to the exclusion criteria, such as smoking habits and refusal to participate, 5 patients were excluded from the sample. Thus, the final sample size was 21 patients. This study involved a higher proportion of female respondents -12 participants (57.14%)-compared to male respondents, with 9 participants (42.86%). The 10-20 year age group had the highest participation, with 18 participants (85.71%). All participants were CLP patients consisting of 14 patients (66.67%) with bilateral CLP and 7 patients (33.33%) with unilateral CLP (Table **1**).

Table 1. Distribution of subjects by age, gender and type of CLP.

-	n (%)
Genader	-
Male	9 (42.86)
Female	12 (57.14)
Age Group	-
10 - 20	18 (85.71)
20 - 30	3 (14.29)
30 - 40	0 (0.00)
CLP	-
Bilateral	14 (66.67)
Unilateral	7 (33.33)

Note: n – Number of subjects.

In this study, the pH and buffer capacity values of patients with non-syndromic cleft lip and palate are presented in Table **2**, which shows that 85.71% had normal pH and 90.48% had very low buffer capacity. Among the 21 subjects, 90.48% had a good Calculus Index (CI), 57.14% had a moderate Debris Index (DI), and 61.90% had a moderate Oral Hygiene Index Simplified (OHI-S) (Table **3**).

Table 2. Salivary pH and buffer capacity in patients with non-syndromic cleft lip and palate.

Variable	f	%
Salivary pH	-	-
Normal	18	85.71
Acidic	2	9.52
Alkaline	1	4.76
Buffer Capacity of Saliva	-	-
Very Low	19	90.48
Low	2	9.52
Normal	0	0.00

Note: f-Frequency.

The results showed no statistically significant correlation between salivary pH and buffer capacity and the Debris Index (Table **4**).

The results showed no statistically significant correlation between pH level and the Calculus Index, while buffer capacity showed a significant correlation with the Calculus Index. The t-test revealed a statistically significant difference between the two groups ($p < 0.05$) (Table **5**).

The results showed that there was no statistically significant correlation between pH level, buffer capacity, and the Calculus Index (Table **6**).

Table 3. Oral hygiene status in patients with non-syndromic cleft lip and palate based on calculus index (CI), debris index (DI), and OHI-S scores.

Variable	Calculus Index (CI)		Debris Index (DI)		OHI-S	
	f	%	f	%	f	%
Good	19	90.48	2	9.52	3	14.29
Moderate	1	4.76	12	57.14	13	61.90
Bad	1	4.76	7	33.33	5	23.81

Note: OHI-S-Oral Hygiene Index Simplified.

Table 4. Correlation of pH and buffer capacity with debris index (DI).

Variable	r	t-test	*p*-value	Significance
pH	0.30	1.39	0.0902	NS
Buffers	-0.14	-0.60	0.2769	NS

Note: t test- t test value; significance value $p < 0.05$, S*-Significant, NS-Non significant.

Table 5. Correlation of pH and buffer capacity with calculus index (CI).

Variable	r	t-test	*p*-value	Significance
pH	-0.13	-0.58	0.2842	NS
Buffers	-0.47	-2.34	0.0152	S*

Note: t test- t test value ; significance value $p < 0.05$, S*-Significant, NS-Non significant.

Table 6. Correlation of pH and buffer capacity with OHI-S.

Variable	r	t test	*p*-value	Significance
pH	0.18	0.78	0.2227	NS
Buffer	-0.22	-0.97	0.1724	NS

Note: t test- t test value; significance value $p<0.05$, S-Significant, NS-Non Significant.

4. DISCUSSION

This study was conducted to evaluate the effect of salivary pH and buffer capacity on calculus formation in fixed orthodontic treatment patients with non-syndromic CLP. Previous studies have shown that patients with cleft lip and palate experience gingivitis and periodontitis and generally have poor oral hygiene [11]. Factors contributing to poor oral health in patients with cleft lip and palate include structural and functional defects [25]. Scar tissue from gap closure surgeries and orthodontic treatment can hinder optimal plaque control [11]. The prevalence and severity of oral diseases in CLP patients are higher compared to the general population [26]. This may be due to low physical ability, difficulty in brushing teeth, limited understanding of the importance of oral health, difficulty in communicating oral health needs, and fear of dental procedures [27].

The Oral Hygiene Index-Simplified (OHI-S) examination is performed on six index teeth because this method is designed to provide a representative overview of a person's oral hygiene efficiently. The six teeth selected represent the anterior and posterior segments of the oral cavity, as they include areas where debris and calculus commonly accumulate. This ensures that the assessment of oral hygiene encompasses different regions in the mouth in a quick, representative, and meaningful manner [20, 22]. Although children with CLP generally have poor oral hygiene [28], the results of this study showed that the level of oral hygiene fell into the moderate category. These findings contradict those of Zahid *et al*., who reported that the majority of CLP patients -54.8% of 49 respondents- had poor oral hygiene [9].

This study showed that the oral health level of respondents was in the moderate category, as indicated by the OHI-S examination results (61.90%). Most participants had a good Calculus Index (90.48%) and a moderate Debris Index (57.14%). These findings may be attributed to the important role of the dentist as a primary motivator during each patient visit throughout active orthodontic treatment in promoting oral health maintenance [29]. Additionally, the patient's knowledge, motivation, awareness, and consistent oral hygiene practices also contribute to these outcomes [30].

The pH of saliva typically ranges from 5 to 8. An alkaline pH plays a role in the deposition of calcium phosphate, thereby increasing plaque mineralization, as reported by Wong L *et al*. [31] Salivary pH in patients with chronic generalized periodontitis was found to be statistically signi-

ficantly higher compared to that of individuals with healthy gingiva. Meanwhile, a study by Lages *et al*. reported that the dental and periodontal health of patients with CLP was comparable to that of the general population [32]. This finding contrasts with the study by Mutthineni, which proved that the periodontal health of CLP patients was poor [11].

The results of this study showed that salivary pH was non significantly related to the Calculus Index (CI) and Debris Index (DI). This finding is in line with the study by Ramisetti *et al*., which also reported no significant relationship between salivary pH and calculus formation, possibly due to a small sample size [33].

Meanwhile, buffer capacity has a significant effect on the Calculus Index (CI) with $p < 0.05$. This finding is consistent with the research by Wulandari, which showed that buffer capacity affects calculus formation [34]. A high salivary buffer capacity supports calculus formation by maintaining the pH value above the critical level, thereby promoting hydroxyapatite saturation in dental plaque. Buffer capacity is closely related to salivary pH and plays an important role in maintaining salivary pH stability [35].

In addition to salivary pH factors, calculus formation in different individuals may be influenced by variations in salivary flow rates across various regions of the oral cavity. Other components of saliva may also contribute to calculus deposition, such as supersaturation of Calcium ($Ca2^{+}$) and phosphate ($P3^{-}$) ions, protein content, and the presence of certain organic acids [35, 36]. Another important factor is viscosity; thicker saliva can facilitate the deposition of calcium and phosphorus minerals, leading to calculus formation. This study did not show a significant relationship between salivary pH and calculus formation in patients with non-syndromic cleft lip and palate, which may be attributed to the limited sample size.

The primary limitation of this study is the relatively small sample size. Therefore, further research involving a larger sample size is necessary to more accurately determine the role of salivary pH and buffer capacity on oral hygiene in orthodontic patients with non-syndromic cleft lip and palate.

CONCLUSION

In conclusion, this study found a non-significant correlation between salivary pH, buffer capacity, and oral hygiene in orthodontic patients with non-syndromic CLP. However, the buffer capacity of saliva showed a significant influence on calculus formation in patients undergoing fixed orthodontic treatment. No significant association was observed between salivary pH, buffer capacity, and oral hygiene, which may be attributed to the small sample size.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: E.S.: Study concept, writing or design; C.N.M.: Data collection and writing; E.S., A.L., C.N.M.: Data analysis, writing or interpretation of results; A.L.: Conceptualization and writing; I.A.E.: Methodology and writing; I.A.E., D.S.L.: Data curation and writing; E.S.: Writing the paper; E.M.: Writing-original draft preparation. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

DI	=	Debris Index
CI	=	Calculus Index
DCPD	=	Dicalcium Phosphate Dihydrate
OCP	=	Octacalcium Phosphate
OHI-S	=	Oral Hygiene Index Simplified
$Ca2^{+}$	=	Calcium
P3	=	Phosphate

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This research has received ethical approval from the Research Ethical Committee of Padjadjaran University, Indonesia No. 531/UN6.KEP/EC/2023.

HUMAN AND ANIMAL RIGHTS

All research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

All subjects provided the signed informed consent after an explanation of the study protocol.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available in the Zenodo Repository at https://zenodo.org/records/15766175, reference number 157661175 (DOI: 10.5281/zenodo.15766175).

FUNDING

This work was financially supported by Academic Leadership Grant (ALG) Unpad, Director of Research and Community Service (DRPM) Padjadjaran University, Indonesia and the grant number is 1445/UN6.3.1/PT. 00/2024.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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